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Evaluation of Seismic Reflection Data in the Davis and Lavender Canyons Study Area, Paradox Basin, Utah

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Technical Report

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ABSTRACT

Seismic reflection data purchased from petroleum industry brokers and acquired through group speculative surveys were interpreted for information on the regional subsurface geologic structure and stratigraphy within and surrounding the Davis and Lavender Canyons study area in the Paradox Basin of southeastern Utah. Structures of interest were faults, folds, joints, and collapse structures related to salt dissolution.

The seismic reflection data were used to interpret stratigraphy by identifying continuous and discontinuous reflectors on the seismic profiles. Thickening and thinning of strata and possible areas of salt flowage or dissolution could be identified from the seismic data. Identifiable reflectors included the tops of the Precambrian and Mississippian, a distinctive interbed close to the middle of the Pennsylvanian Paradox salt formation (probably the interval between Salt Cycles 10 and 13), and near the top of the Paradox salt.

Of the 56 faults identified from the seismic reflection interpretation, 33 trend northwest, west-northwest, or west, and most affect only the deeper part of the stratigraphic section. These faults are part of the deep structural system found throughout the Paradox Basin, including the fold and fault belt in the northeast part of the basin. The faults bound basement Precambrian blocks that experienced minor activity during Mississippian and early Pennsylvanian deposition, and showed major displacement during early Paradox salt deposition as the Paradox Basin subsided. Based on the seismic data, most of these faults appear to have an upward terminus between the top of the Mississippian and the salt interbed reflector.

FOREWORD

The National Waste Terminal Storage (NWTS) program was established in 1976 by the U.S. Department of Energy's (DOE) predecessor, the Energy Research and Development Administration. In September 1983, this program became the Civilian Radioactive Waste Management (CRWM) Program. Its purpose is to develop technology and provide facilities for safe, environmentally acceptable, permanent disposal of high-level waste (HLW). HLW includes wastes from both commercial and defense sources, such as spent (used) fuel from nuclear power reactors, accumulations of wastes from production of nuclear weapons, and solidified wastes from fuel reprocessing.

The information contained in this report pertains to the Paradox Basin geologic studies of the Salt Repository Project of the Office of Geologic Repositories in the CRWM Program.

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1.0 INTRODUCTION

Investigations were conducted by Woodward-Clyde Consultants (WCC) between 1979 and 1983 to identify surface and subsurface structures present in the vicinity of the Davis and Lavender Canyons in the Paradox Basin, Utah, that could impact nuclear waste repository siting or licensing. Structures of concern included faults, folds, joints, and collapse structures related to salt dissolution. These structures are significant because they may affect the tectonic stability of the area surrounding a repository and the subsurface integrity of the underground operations area. Both surface and subsurface information was collected. The surface data were primarily from field mapping, aerial photography, and satellite imagery. The subsurface information included existing well logs and geophysical data (seismic reflection, gravity, and aeromagnetic). This report describes the seismic reflection data that were acquired and summarizes the data interpretation completed to date for the Davis and Lavender Canyons study area by Woodward-Clyde Consultants.

1.1 STUDY AREA AND DATA ACQUISITION

The study area includes the Gibson Dome fold, the fault systems in the vicinity of the Needles area and the Abajo Mountains (Shay-Bridger Jack-Salt Creek graben system and Verdure graben), and the Lockhart Basin collapse structure (Figure 1-1).* Seismic reflection data were acquired for locations where information on the subsurface extent and configuration of these structural features could be evaluated. The data were also interpreted for stratigraphic studies; for example, reflection data were acquired in Davis Canyon not only to verify the absence of subsurface structures, but also to confirm estimated stratigraphic thicknesses in the vicinity of the proposed repository location. The stratigraphic section included the Precambrian through the Permian. The seismic reflection data in the Paradox Basin allowed the identification of geologic horizons, including the tops of the Precambrian basement, Mississippian Leadville Limestone, significant interbeds within the Paradox Formation, and the structures that affect them.

1.2 APPROACH

This phase of study of the geologic structure in the Davis and Lavender Canyons study area involved selecting, acquiring, and interpreting seismic reflection data and comparing the interpreted data with information from drillholes and detailed mapping. Data selection and acquisition took place between 1980 and 1982; data interpretation and geologic analysis took place during 1982 and 1983. A seismic reflection consultant, J. J. Richard, Inc., of Englewood, Colorado, was selected to assist in data selection, acquisition, and interpretation.

Seismic reflection data that were available were the result of the many oil exploration efforts conducted in the Paradox Basin since the 1950s; rights

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* Tables and Figures are attached at the back of the report.

to use these proprietary data were purchased through brokers. Additional seismic data were purchased as part of a group speculative survey, where participants can specify line or station locations and data resolution. Because such data are owned by all the participants in the original surveys, the data are considered proprietary, and cannot be reported in original format by one participant. Original data purchased by Woodward-Clyde Consultants, including shotpoint locations, remain in WCC files.

2.0 SEISMIC REFLECTION DATA

2.1 SELECTION AND ACQUISITION

Data were selected to obtain broad regional subsurface information in addition to providing more detailed information over specific structures of interest. Data quality was an important consideration in the selection process, but subordinate to location in areas where data were needed. Consequently, even marginal quality data were obtained where necessary if it appeared possible to improve the data quality by reprocessing. Data resolution was considered an important factor in the selection process. Because shotpoint spacing significantly impacts the resolution of the subsurface structure (reflecting horizons and faults), the data sets having the closest spacing were chosen. Approximately 50 percent of the seismic reflection data available from the study area were considered suitable for purchase and evaluation.

2.2 DATA REPROCESSING

Most of the seismic reflection lines purchased were originally acquired by oil companies; their specific geologic exploration target was usually the Mississippian Leadville Limestone. Most of the seismic reflection profiles from these surveys were processed to obtain detail in the deepest (Mississippian and Precambrian) part of the stratigraphic section. The quality of the data for the shallower reflectors, such as the Paradox salt and Permian sandstones, could be improved by digitally reprocessing these lines using processing parameters more suitable for reflection times from shallower horizons. Therefore, some of the oil company seismic lines were reprocessed. Several of the speculative survey seismic lines were also reprocessed to improve interpretability. Approximately 75 percent of all lines purchased for the project were reprocessed; interpretability of the seismic data improved in most cases. Only those seismic lines that needed no reprocessing or that showed improved interpretability after reprocessing were interpreted for this study. A total of 43 lines were interpreted (Figure 2-1); specifications for these lines are presented in Table 2-1.

2.3 DATA ANALYSIS

During the seismic reflection interpretation, the reflectors that characterize the different strata on each profile were identified using known borehole data, correlations from tie points at profile intersections, and professional experience. Judgment was required in deciding the source of reflector discontinuities; these may be caused by such factors as noise in the data, terrain constraints of the survey itself, changes in lithology, lenticular beds, or possible faults and dissolution features. The reflection data were migrated in areas of steeper dips (greater than 8 degrees) to improve the structural interpretation and the identification of faults. Faults interpreted from the reflection data were subjectively rated good, fair, or poor, based on the quality of the data. The faults are summarized in Chapter 3.

Although a seismic line may cross a particular fault, the fault might not be observed because of a poor approach angle or data quality, or if the displacement was below the limit of resolution. The resolution limit of the seismic data was approximately 15 m (50 ft) at the depths of the Precambrian and Mississippian horizons. Fault displacements less than this amount were generally not observable. The resolution limit increased (or degraded) to 30 to 60 m (100 to 200 ft) in the shallower sections especially above the top of salt.

Reflection-time contours of the top of the Mississippian and top of salt were constructed using the interpreted seismic reflection profiles at contour intervals of 0.05 sec and 0.10 sec. The contoured values are two-way travel times below a datum elevation of 1,554 m (5,100 ft) above mean sea level. In areas where seismic line coverage was sparse, data from available downhole velocity surveys were converted to equivalent reflection time data points for compiling the reflection time contour maps of the top of salt and the top of the Mississippian.

3.0 SEISMIC REFLECTION INTERPRETATION

Interpretation of the seismic profiles identified 59 faults. Eleven of these faults are located either north of the study area near Salt Valley or south of the area near Elk Ridge and are not discussed in this report. Figures 3-1 and 3-2 illustrate the relationship between the seismic lines and the remaining 48 faults in the Mississippian and the top of salt, respectively. Table 3-1 lists the faults, their trend, sense and amount of throw, and dip of the fault planes, and the reflectors affected. Also shown are six additional faults that were interpreted solely from well control in areas where no seismic data were available. Table 3-2 lists those faults and the relevant wells used. The reflection time contours, sense and amount of throw, dip of the fault planes, and quality of the data for the interpretation of the faults are also shown on Figures 3-1 and 3-2.

The seismic reflection data were used to interpret stratigraphy by identifying continuous and discontinuous reflectors on the seismic profiles. Thickening and thinning of strata and possible areas of salt flowage or dissolution can be identified from the seismic data. Identifiable reflectors included the tops of the Precambrian and Mississippian, a distinctive interbed close to the middle of the Pennsylvanian Paradox salt formation (probably the interval between salt cycles 10 and 13), and the top of the Paradox salt. Some areas also show a Devonian reflector beneath the Mississippian Leadville Limestone and a Permian and/or Pennsylvanian reflector above the Paradox Formation.

More than half (33) of the faults identified from the seismic reflection interpretation trend northwest, west-northwest, or west, and most of these faults affect only the deeper part of the stratigraphic section (Precambrian and Mississippian) (Table 3-1). The faults in this category are part of the deep structural system found throughout the Paradox Basin, including the fold and fault belt in the northeast part of the basin. These faults bound basement Precambrian blocks that were present and experienced minor activity during Mississippian and early Pennsylvanian deposition, based upon isopach patterns (McCleary and Romie, 1986). The faults also showed major displacement during early Paradox salt deposition as the Paradox Basin subsided (WCC, 1982, Vol. I, p. 7-16). Based on the seismic data, most of these faults appear to have an upward terminus between the top of the Mississippian and the salt interbed reflector (Table 3-1).

An unusual feature of the faults bounding the graben structures (Verdure and Shay systems) is a nested configuration that results in decreasing structural width up to and including the surficial expression (Figure 3-3). This will be discussed further in Sections 3.1 and 3.2.

3.1 SHAY GRABEN SYSTEM

The Shay graben system includes Shay, Bridger Jack, and Salt Creek grabens, which appear to be en echelon. All three grabens trend east-west to northeast, and are south of Davis and Lavender Canyons (Figure 1-1). Seismic lines 33 through 36 and 43 cover this area (Figure 2-1, Sheet 1). Line 33 was purchased as existing data. WCC was an original participant in a speculative survey of the other lines. Shay graben presents some difficulties for reflection surveys because of its long, narrow structure. Specifications of the seismic surveys had to be specifically planned to yield usable seismic profiles across the graben. The purchased seismic data did not have the specifications to resolve such a narrow structure.

Seismic line 33 was first interpreted for Shay graben (faults DD and EE; Figure 3-1, Sheet 2); lines 34 and 35 were later acquired at a closer shotpoint spacing (Table 2-1). Line 33 follows Highway 211, which has a right-angle switchback turn as it crosses through the graben. The line intersects the north fault of Shay graben at an acute angle, enters the graben zone, and recrosses the north fault to leave the graben zone. This configuration causes noise in the data as well as sideswipe (overlapping reflections); thus, the characteristics of the faults are poorly defined.

Seismic lines 34 and 35 cross the northeastern end of Shay graben (Figure 2-1, Sheet 1). The maximum surface throw associated with Shay graben is estimated to be 98 m (320 ft) near Indian Creek (WCC, 1982, Vol. II, p. 6-4). Analysis of line 34 shows the graben (faults DD and EE) cutting the Precambrian and Mississippian with a displacement of 30 m (100 ft) on each fault, a continuous salt interbed reflector above faults DD and EE, and a continuous top of salt reflector above fault DD (Figure 3-3). An upper graben bounded by faults KK and LL above the interbedded salt reflector is weakly suggested by the data (Figure 3-2, Sheet 2). This interpretation suggests that the salt is undisturbed by the deeper graben. However, the observed surface displacement at this location along Shay graben is confined to the Navajo Sandstone, which has an average thickness of 61 m (200 ft) in this location, and estimates of vertical surface offset (throw) made during surface mapping are on the order of 3 to 9 m (10 to 30 ft). It is possible that the graben could extend upward to faults KK and LL, and cut the whole salt section with a throw of less than 15 m (50 ft) (limit of resolution). However, the stratigraphic relationship of the upper graben to the lower graben, based on the seismic data, would argue against continuous faults. At this time, a mechanism for the nested configuration of the two grabens is not known. One hypothesis is that the surface graben is the result of dissolution and collapse. However, the seismic data do not clearly indicate the presence or absence of dissolution in the vicinity of seismic line 34 as it crosses over Shay graben. Additional information will be needed to understand the relationship (if one exists) between the upper and lower grabens.

Seismic line 35 is 6 km (4 mi) northeast of line 34 near the eastward terminus of Shay graben (Figure 2-1, Sheet 1). No evidence of the graben is apparent on the seismic data. At the surface, the north fault of Shay graben appears to be dying out and the only mappable outcrops show a displacement of less than 6 m (20 ft). At the southern end of line 35, fault F is a northwest-trending fault probably related to the Flat Iron Mesa faults to the north (Figure 3-1, Sheet 1) (Section 3.8).

Seismic line 36 crosses Bridger Jack graben and the southwestern terminus of Shay graben (Figure 2-1). The interpretation shows Shay graben faults DD and EE in this location to have 30 m (100 ft) of vertical throw and only displacing the top of the Mississippian (Figure 3-1, Sheet 2). Within the limits of the resolution, faults KK and LL do not appear to exist at this location.

Fault FF, south of Shay graben along line 36, has a throw of 15 m (50 ft) and cuts the Precambrian and Mississippian (Figure 3-1, Sheet 2). Because of the small offset, this fault may continue upward through the salt reflectors, without being observable in the seismic data. No mapped surface fault occurs at the location of fault FF.

Bridger Jack graben is encountered northward along line 36 (faults II and HH); the throw could not be estimated because of lack of resolution within the graben (Figure 3-1, Sheet 2). These faults cut the Precambrian and the Mississippian reflectors, and do not appear to extend upward through the salt reflectors. However, Bridger Jack graben (Figure 2-1, Sheet 1) has been mapped at the surface above the upward projection of faults II and HH, so the offset may be less than the resolution limit of the seismic data, and the faults may continue through to the surface. The throw mapped at the surface 1.6 km (1 mi) west of the seismic line is approximately 30 m (100 ft).

Fault JJ, south of the Bridger Jack graben faults II and HH, has a throw of 21 m (70 ft) on the Mississippian horizon and appears in the reflection data to die out before reaching the overlying salt (Figure 3-1, Sheet 2). However, because it appears to coincide with a small surface splay off Bridger Jack graben (Figure 2-1, Sheet 1) that has a mapped surface throw of 3 to 6 m (10 to 20 ft), it is possible that fault JJ extends upward from the Mississippian to the surface, with vertical offsets in the overlying salt horizons below the level of resolution.

North of Bridger Jack graben along line 36, fault GG cuts the Precambrian and Mississippian reflectors, and has an estimated throw of 21 m (70 ft) (Figure 3-1, Sheet 2). No mapped surface fault occurs at the upward projection of fault GG. If this fault is projected to the northeast, it should cross seismic line 33B (Figure 3-1, Sheet 2). Because it is not expressed on line 33B, the fault is interpreted to be dying out toward the northeast.

Seismic line 43 trends southeast from the Needles fault zone, across Salt Creek graben, into Beef Basin (Section 3.5). In the Salt Creek graben area, the line was not interpretable, thus no faults were identified. In the Shay graben area, the line crosses the north fault of the graben (DD), a western projection of the south fault (EE), and fault GG (Figure 3-1, Sheet 2). The seismic data indicate that Shay graben probably extends farther west than has been mapped at the surface. The subsurface extent of at least the lower graben is 4 to 5 km (2.5 to 3 mi) farther to the west. The western end of Shay graben is similar in structural style to Bridger Jack and Salt Creek grabens, and has similar displacement, lending strength to the hypothesis that these grabens are probably part of one system.

More data are needed to evaluate whether the Shay graben is the result of tectonic faulting, dissolution, or both; this question could be resolved by drilling and detailed seismic studies in the vicinity of maximum displacement along the graben. If the faults penetrate the salt, dissolution is possible if ground-water recharge is occurring along the fault planes. However, the seismic data do not seem to indicate any dissolution. The lack of dissolution features identifiable in the seismic data may suggest that (1) the Shay graben faults have been healed by salt flow and are not conduits for ground-water flow, or (2) the graben was reactivated in recent time and ground water has not yet affected the salt there. The question of ground-water recharge along the faults could also be resolved by drilling in the vicinity of Shay graben.

3.2 VERDURE GRABEN

Seismic line 40A crosses Verdure graben (Figure 2-1, Sheet 1); the graben is bounded by faults I and I' (Figure 3-1, Sheet 2; latter fault not shown). The south fault (I) has a throw of 46 m (150 ft) and cuts the whole section from the Precambrian to the surface (Figure 3-3). Its upward projection coincides with the mapped location of the surface fault. The north fault (I'), which is adjacent to the Abajo Mountains, appears to be antithetic to fault I. It cuts down from the surface and merges with the south fault just below the top of salt reflector.

Stratigraphically below this graben, another graben is formed by faults H and J; H appears to be antithetic to fault I (Figure 3-3). These faults cut the Precambrian through much of the salt although fault J does not displace the top of salt within the resolution of the data. Fault J has a throw of 46 m (150 ft); fault H has a throw of 76 m (250 ft). Faults H, I, and J were probably active during postsalt time, and fault I was probably reactivated during post-Mesozoic time, resulting in the formation of fault I'. As in the case of Shay graben at the intersection of seismic line 34, the "nested" configuration of these grabens is unusual and unexplained at this time.

Faults K and L occur parallel to and south of Verdure graben along line 40A (Figure 3-1, Sheet 2). These faults cut only the Precambrian and Mississippian part of the section, but only fault L has a clearly observable vertical offset--69 m (225 ft) down on the north. South of faults K and L, fault M is also parallel to Verdure graben. Fault M cuts the Mississippian through top of salt reflectors and has a throw of 84 m (275 ft) down on the north (Figures 3-1, Sheet 2 and 3-2, Sheet 2). It is not known whether faults K, L, and M are structurally related to Verdure graben; none of them has surface expression.

Seismic line 42 crosses the western end of Verdure graben (Figure 2-1, Sheet 1). The absence of faults in the reflectors suggests a subsurface termination of the graben west of this location. However, faults could be present with displacements smaller than the limits of resolution since the Verdure graben is still observable at the surface at this location.

3.3 LOCKHART BASIN AND HATCH MESA AREA

The area surrounding Lockhart Basin and the Hatch Mesa area to its southeast had the most extensive seismic coverage of any of the structures examined for this study; 26 seismic lines were interpreted for this area (Table 3-3). Only two lines are within Lockhart Basin; the others are on the northeast, southeast, and southwest perimeters of the basin (Figure 2-1, Sheets 2 and 3).

Seismic lines 38 and 39 (Figure 2-1, Sheet 2) were interpreted to define the lateral boundaries of dissolution and collapse around Lockhart Basin, a collapse feature where dissolution has removed salt from the section. Seismic line 38 shows salt present along its entire length; it intersects line 39 at the edge of Lockhart Basin. Line 38 also indicates that salt continues to a point 1.6 km (1 mi) north of the Flying Diamond well (Figure 2-1, Sheet 1). No interpretable reflectors appear east of the northwest-trending fault O on line 39, probably because of the collapsed and brecciated sediments in the basin.

Seismic line 39 pinpoints the northwest boundary of collapse within Lockhart Basin (Figure 2-1, Sheet 2). Seismic lines 2 and 3, bordering the northeast and southeast sides of the basin, both indicate salt present, so the northeastern and southern boundaries of collapse seem to follow the topographic perimeter of Lockhart Basin.

Seismic line 1 (Figure 2-1, Sheet 3) trends northwest-southeast and is located east of Lockhart Basin on Hatch Mesa. Line 31 (Figure 2-1, Sheet 2) trends west and then northwest into the same vicinity. Both lines cross the Lockhart fault (CCC) and show it to be down to the southeast (Figure 3-2, Sheet 1). The Lockhart fault displaces the top of salt and may displace one of the salt interbed reflectors; it does not extend downward below the salt to displace the Mississippian reflector. Because the Lockhart fault does not affect the entire stratigraphic section, it is probably a tensional feature resulting from collapse of the Lockhart Basin.

Many northwest-trending faults cut the Mississippian reflectors (Figure 3-1, Sheet 1)*. The faults in this northwest-trending group include faults O, P, Q, S, U, V, W, X, AA, and JJJ (Table 3-1). In the vicinity of Lockhart Basin, the faults are spaced 1.6 to 5 km (1 to 3 mi) apart. Only fault O displaces both the Mississippian and the top of salt reflectors in this area (Figure 3-2, Sheet 1).

Fault JJJ (Figure 3-1, Sheet 1) was interpreted solely from well control** (Table 3-2). It is down on the southwest and is probably related to the block faulting common in the Lockhart Basin area. Fault KKK was also interpreted solely from well control (Figure 3-2, Sheet 1; Table 3-2). It is parallel to fault Q, which cuts the Mississippian surface (Figure 3-1, Sheet 1), but it is not the same fault; fault Q does not cut upward through the salt section. Fault KKK is probably similar in origin to fault CCC, that is, a tensional feature resulting from collapse of the basin. It is down on the northeast, and is located within what is now the collapsed part of the basin, so it could be part of the downward sagging that took place after salt

* This plan view also covers the Flat Iron Mesa area (Section 3.8); some faults in that area extend into Lockhart Basin.

** Although fault JJJ is crossed by seismic line 30, poor data quality did not allow sufficient definition of the fault.

dissolution began. Unlike fault CCC, fault KKK does not have surface expression.

The Lockhart Basin faults are interpreted to have throws in the range of 21 to 396 m (70 to 1,300 ft). Half of the northwest-trending faults have vertical offsets of approximately 91 m (300 ft). These faults are probably part of the northwest-trending Precambrian fault block system that controlled the location of the salt anticlines in the northeastern part of the basin. The southwestern margin of this fault block system borders the northeastern margin of the Gibson Dome fold. The fold appears to mark the limits of folding caused by flowage in Paradox salt deposits because the stratigraphy becomes more flat-lying to the southwest. The seismic reflection interpretation supports this hypothesis within its limits of resolution.

Seismic lines 18, 25, and 26 cross fault T, a small northeast-trending fault (Figure 3-1, Sheet 1) that is down on the northwest and has 46 m (150 ft) of throw. Faults ZZ (line 32) and DDD (line 26), are small faults that displace the Precambrian reflector only (Table 3-1). Fault III, interpreted from line 38, is a small fault that displaces only a Pennsylvanian reflector. The small displacement of these faults, with the exception of fault T, is indeterminable because they were below the limits of resolution.

The most significant new information about Lockhart Basin from the seismic data is the expression of the large northwest-trending Mississippian faults underneath the basin. These faults are probably part of a Precambrian fault system that experienced minor movement during the early Paleozoic and major reactivation when the Paradox Basin subsided during the Pennsylvanian (McCleary and Romie, 1986).

One theory on the origin of Lockhart Basin involves the circulation of ground water between the Mississippian aquifer and the Pennsylvanian salt, which was deposited against the Mississippian across the plane of fault O. This ground-water circulation began the process of dissolution in post-Mesozoic time, and the fault extended through the top of salt as a tensional feature related to the dissolution and collapse of the basin.

It is probable that the bulk of the dissolution and collapse predates the Quaternary downcutting of the Colorado River. Assuming that the Lockhart fault was tensional, resulting from dissolution and collapse, Quaternary displacement on the Lockhart fault would indicate active dissolution. Trenching studies of the Lockhart fault would address the question of Quaternary movement.

3.4 GIBSON DOME FOLD

Seismic lines 33B and 37 cross the Gibson Dome fold axis at approximately a right angle (Figure 2-1, Sheet 1); seismic line 30 bends across the fold axis from perpendicular to parallel (Figure 2-1, Sheet 2). Seismic line 30 shows a subtle thickening of salt as the fold axis is crossed. Data are discontinuous on seismic line 33B because of terrain difficulties in Indian Creek; therefore the expression of the fold along this line is poor. Line 38, which runs parallel to the fold at its southern end, reveals a small fault

(FFF) that appears to displace the salt interbed, top of salt, and Pennsylvanian reflectors but has no mapped surface expression (Figure 3-2, Sheet 1).

All seismic lines in the area indicate that the Mississippian reflector is flat or slightly synclinal beneath the fold. The thickening of salt could be a result of some salt flowage, increased deposition in the Mississippian syncline, or probably both. If the fold is the result of compression, the salt may have acted as a detachment zone between pre-salt and post-salt units. The fold seems to be undisturbed by faulting except for fault FFF, which is tensional, reflecting salt flowage from the flank of the fold.

3.5 NEEDLES FAULT ZONE

The terrain surrounding the Needles Fault zone is rugged, providing few locations for conducting seismic surveys. Seismic line 43 lies across the southeastern portion of this zone (Figure 2-1, Sheet 1), but its interpretability was severely limited even after reprocessing. The northwest end of line 43, where the Needles faults would cross it, has little useful data; only the Mississippian reflector is observable and it has poor interpretability. Where the Mississippian reflector is observable, it is not disturbed by faulting, so the Needles faults appear to be confined to post-Mississippian strata. More detailed seismic surveys are needed in this area to provide information about the Needles faults.

3.6 DAVIS CANYON

The southern half of seismic line 37 covers Davis Canyon (Figure 2-1, Sheet 1) and passes by the proposed repository location. Fault EEE, identified in the vicinity of Davis Canyon, is a normal fault that cuts only the Precambrian reflectors. Fault EEE has 30 m (100 ft) of throw, down to the north. Interpretation of the section above this fault indicates that the other reflectors are undisturbed, and dip gently toward the basin in this vicinity.

The northern part of seismic line 37 shows fault R located 3 km (2 mi) northeast of the potentially acceptable repository location (Figure 3-1, Sheet 1). This fault, which also appears on seismic line 33B, cuts the Precambrian through Mississippian reflectors and has an estimated throw of 50 m (165 ft) down to the southeast. This fault does not displace the salt reflectors and is probably confined to the deeper part of the stratigraphic section.

Seismic line 37 was also interpreted to help estimate depths to the top of the Paradox Formation and the top of Salt Cycle 6 (potentially acceptable repository host rock unit) beneath six shotpoint locations (designated by points A through F on Figure 3-4) near the potentially acceptable repository location. To obtain depths to the top of salt, elevations of the top of salt based on line 37 were subtracted from the elevation of the ground surface at each point, taken from a topographic map (Table 3-4). The borehole geophysical log from borehole GD-1 (Figure 2-1, Sheet 1) was then used to calculate the interval thickness between the top of salt and the top of Salt

Cycle 6 which was estimated to be 58 m (190 ft). Because the seismic interpretation suggested a fairly uniform thickness between the top of salt and individual salt cycles in the area between borehole GD-1 and the potentially acceptable repository location, 58 m (190 ft) was subtracted from the depth to top of salt to arrive at the depths to Salt Cycle 6. These depths to the top of Salt Cycle 6 at points A through F have an estimated error of ± 30 m (100 ft) (Table 3-4).

3.7 CANE CREEK ANTICLINE

Seismic lines 6, 7, 8, and 21 were located in the area of Cane Creek anticline (Figure 2-1, Sheet 3). The interpretation of seismic line 6 shows a thickening of salt as the axis of the anticline is approached. Fault Y, which has a throw of 46 to 183 m (150 to 600 ft) down on the southwest, cuts the Mississippian (Figures 3-1, Sheet 1) but not the top of salt. It is probably one of the northwest-trending faults that influenced salt flowage along the Cane Creek anticline, as did other faults in the Paradox fold and fault belt to the northeast.

Seismic line 8 shows fault XX as a small fault that cuts the Precambrian and is down on the northeast, suggesting that it is a northwest-trending fault. However, the fault only appears on seismic line 8 and its trend is questionable. Fault XX is located 2.4 km (1.5 mi) north of the Trough Springs Canyon surface fault, which trends northeast. No expression of the Trough Springs Canyon fault, at least in the Mississippian and Precambrian, is indicated where it is projected to cross seismic line 8. However, this seismic line does not have good interpretability in the salt or younger reflectors, so the fault may actually displace these units. Fault Y also appears on seismic line 8 (Figure 3-1, Sheet 1).

Northeast of the Cane Creek anticlinal axis, seismic line 21* shows northwest-trending faults Z and AB as a horst in the Mississippian (Figure 3-1, Sheet 1). Southwest of fault Z, the salt thickens as the Cane Creek anticlinal axis is approached. Seismic line 41 also shows fault AB (Figure 3-1, Sheet 1).

The Trough Springs Canyon fault is parallel or en echelon with the Lockhart fault, suggesting that both could be related to dissolution and collapse; however, no evidence of salt dissolution appears on any of the seismic lines crossing Cane Creek anticline. The fault throw as measured at the surface is 61 m (200 ft), which may not be detectable at depth given the poor interpretability of line 8.

3.8 FLAT IRON MESA/LISBON VALLEY FAULT ZONE

Flat Iron Mesa lies between the Lisbon Valley and Cane Creek anticlines (Figure 2-1, Sheet 1), and is within the Paradox fold and fault belt. All of the faults in this area trend west or northwest, parallel to the faults that

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* The south end of line 21 shows an excellent cross-section representation of the anticlinal form.

bound the salt anticlines in the northeastern part of the Paradox Basin. This area also includes the Lisbon Valley faults, which were outside the area of seismic coverage of this report. AAA, BBB, GGG, and HHH were interpreted solely from well control (Figure 3-1, Sheet 1; Figure 3-2, Sheet 1; and Table 3-2). Fault A is a splay from Lisbon Valley fault BBB and was also interpreted from well control. All of the faults in the Flat Iron Mesa area except GGG and HHH cut up through the Mississippian; faults B, BB, GGG, and HHH cut the top of salt.

Seismic lines 16, 17, and 19 (Figure 2-1, Sheets 2 and 3) show faults in the western part of Flat Iron Mesa. Faults B and BB form a graben centered under Hatch Wash Canyon, a minor drainage west of Highway 163 (Figure 3-1, Sheet 1). The graben structure is best seen on seismic line 17. The graben cuts all reflectors from the Precambrian through the top of salt. Throw on the southwest fault B is 46 m (150 ft); no expression of this graben is observable at the surface. Fault C is parallel to fault B (Figure 3-1, Sheet 1), and was interpreted from well control.

Seismic line 35 runs north from the eastern terminus of Shay graben into the Flat Iron Mesa area (Figure 2-1, Sheet 1). Line 41A lies east of and roughly parallel to the southern half of line 35 and is an extension of line 40B. Both lines indicate faults in the extreme southern part of the Flat Iron Mesa area, just northeast of Shay graben. Fault CC appears on seismic line 35; faults D and F appear on seismic lines 35 and 41A (Figure 3-1, Sheet 1). Fault E appears only on seismic line 41A (Figure 3-1, Sheet 1). Fault G appears on seismic line 40B to the south and cuts the Mississippian and Precambrian (Figure 3-1, Sheet 2). Faults D, E, F, and G are parallel.

Faults AB and Y extend into the Flat Iron Mesa area from the Cane Creek anticline area to the northeast. Fault AB is down on the northeast and is parallel to fault Y; it was interpreted from well control (Figure 3-1, Sheet 1).

3.9 COMPARISON OF MAPPED FAULTS AND FAULTS BASED ON SEISMIC REFLECTION DATA

A comparison between mapped surface faults and faults mapped from the Mississippian seismic data (Figure 3-5) showed few coincidences; the only faults that appear to continue through the whole stratigraphic section are those of Verdure graben and possibly Shay graben (although its nested configuration suggests discontinuous faulting). Surface faults were also compared with the interpreted top of salt faults (Figure 3-6); the only faults common to both are the Lockhart fault and the faults of Shay and Verdure grabens.

4.0 REFERENCES

McCleary, J. R., and J. E. Romie, 1986. Stratigraphic and Structural Configuration of the Navajo (Jurassic) through Ouray (Mississippian-Devonian) Formations in the Vicinity of Davis and Lavender Canyons, Southeastern Utah, BMI/ONWI-594, prepared by Woodward-Clyde Consultants for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Woodward-Clyde Consultants, 1982. Geologic Characterization Report for the Paradox Basin Study Area, ONWI-290, Vols. I and II, prepared for the Office of Nuclear Waste Isolation, Battelle Memorial Institute, Columbus, OH.

Table 2-1. Seismic Reflection Surveys

Seismic Line No.	Trend	Date of Survey	Energy Source	Shotpoint No. of Channels	Spacing (feet)	Approximate Line Length (miles)
1	NW-SE	1968	Dynamite	24	1,320	10
2	NE	1968	Dynamite	24	1,320	6
3	NE	1968	Dynamite	24	1,320	10
4	NW	1968	Dynamite	24	1,320	3
5	NE	1968	Dynamite	24	1,320	6
6	NE	1968	Dynamite	24	1,320	5
7	NE	1968	Dynamite	24	1,320	3
8	NW	1968	Dynamite	24	1,320	8
9	E-W	1968	Dynamite	24	1,320	2
10	NE	1968	Dynamite	24	1,320	4
11	NE	1968	Dynamite	24	1,320	6
12	NE	1969	Dynamite	24	1,320	6
13	NE	1969	Dynamite	24	1,320	6
14	NW	1969	Dynamite	24	1,320	3
15	NE	1969	Dynamite	24	1,320	5
16	NE	1969	Dynamite	24	1,320	5
17	NE	1969	Dynamite	24	1,320	8
18	E-W	1969	Dynamite	24	1,320	4
19	NE	1969	Dynamite	24	1,320	3
20	NW	1969	Dynamite	24	1,320	2
21	N-S	1969	Dynamite	24	1,320	4
22	NE	1969	Dynamite	24	1,320	3
23	N-S	1974	Dynamite	48	1,320	6
24	NW	1974	Dynamite	48	1,320	3
25	NE	1974	Dynamite	48	1,320	6
26	NW	1974	Dynamite	48	1,320	5
27	NE	1974	Dynamite	48	1,320	3
28	NW	1974	Dynamite	48	1,320	6
29	N-S	1974	Dynamite	48	1,320	3
30	NE	1974	Vibrator	48	660	6
31	W	1979	Vibrator	48	440	30
32	W	1982	Vibrator	48	440	20
33	SW,NW,N	1980	Vibrator	48	440	37
34	NW	1982	Vibrator	96	440/220	14
35	N	1982	Vibrator	96	220	15
36	N,NE	1982	Vibrator	96	440	22
37	NE	1981	Vibrator	96	440	11
38	NW	1981	Vibrator	96	440	8
39	NW-SE	1981	Vibrator	48	440	2
40	N-S	1979	Vibrator	48	440	15
41	N-S	1979	Vibrator	48	440	21
42	N	1981	Vibrator	48	440	4
43	SE,S	1982	Vibrator	96	440	24

Note: 1 ft = 0.3048 m; 1 mi = 1.6093 km.

Table 3-1. Faults Identified During Seismic Reflection Investigation

Fault Designation	Approximate Trend	Down on the:	Throw (ft)[a]	Dip (Degrees)	Reflectors Affected
A	Northwest	Northeast	150	80	Precambrian through Mississippian
B	Northwest	Northeast	150	70	Precambrian through Top of Salt
C	WNW	North	150	70	Precambrian through Mississippian
D	Northwest	Southwest	70-600	70	Precambrian through Mississippian
E	Northwest	Southwest	150	70	Precambrian through Mississippian
F	Northwest	Northeast	150	70	Precambrian through Mississippian
G	Northwest	Northeast	70	70	Precambrian through Mississippian
H	WNW	South	250	70	Precambrian through Top of Salt
I	WNW	North	150	80	South fault: Precambrian through Surface
I'	WNW	South	-	80	North fault: Top of Salt through Surface
J	WNW	North	150	75	Precambrian through Interbedded Salt
K	WNW	-	-	-	Precambrian (?) through Mississippian
L	WNW	North	225	70	Precambrian (?) through Mississippian
M	WNW	North	275	70	Precambrian (?) through Top of Salt
N[c]	WNW	South	500	75	Precambrian (?) through Interbedded Salt
O	Northwest	Southwest	50-1,300	80	Precambrian through Top of Salt
P	Northwest	Northeast	200	80	Precambrian through Mississippian
Q	Northwest	Northeast	200	70-80	Precambrian through Mississippian
R	Northeast	Southeast	165-265	70	Precambrian through Mississippian
S	Northwest	Northeast	100	80	Precambrian through Interbedded Salt
T	Northeast	Northwest	150	80	Precambrian through Interbedded Salt (?)
U	Northwest	Northeast	70-650	80	Precambrian through Interbedded Salt
V	Northwest	Northeast	100-800	60	Precambrian through Mississippian
W	Northwest	Northeast	50	60	Precambrian through Mississippian
X	Northwest, North-South	East	70	70	Precambrian through Mississippian
Y	Northwest	Southwest	150-600	70	Precambrian through Mississippian
Z	Northwest	Southwest	-	-	Precambrian through Mississippian

Table 3-1. Faults Identified During Seismic Reflection Investigation (Page 2 of 2)

Fault Designation	Approximate Trend	Down on the:	Throw (ft)[a]	Dip (Degrees)	Reflectors Affected
AA	Northwest	Southwest	300	75	Precambrian through Mississippian
BB	Northwest	Southwest	-	80	Precambrian through Top of Salt
CC	Northwest	Northeast	150	70	Mississippian
DD	Northeast	Southeast	100	80	Precambrian through Mississippian
EE	Northeast	Northwest	100	80	Precambrian through Mississippian
FF	Northeast	Northwest	50	80	Precambrian through Mississippian
GG	Northeast	Northwest	70	80	Precambrian through Mississippian
HH	Northeast	Southeast	-	80	Precambrian through Mississippian
II	Northeast	Northwest	-	80	Precambrian through Mississippian
JJ	Northeast	Northwest	70	80	Precambrian through Mississippian
KK	Northeast	Southeast	100	180	Top of Salt through Pennsylvanian (?)
LL	Northeast	Northwest	100	80	Top of Salt through Pennsylvanian (?)
VV	Northeast	Northwest	70	80	Mississippian
XX	Northwest(?)	Northwest(?)	150	60	Precambrian
ZZ	Northwest(?)	Southwest(?)	-	-	Precambrian
AB	Northwest	Northeast	1,000	-	Precambrian through Mississippian
AAA[b]	Northwest	Northeast	-	-	Precambrian through Mississippian
BBB[b]	Northwest	Northeast	2,400	-	Precambrian through Mississippian
CCC	Northeast	Southeast	150-300	80	Interbedded Salt through Top of Salt
DDD	Northeast(?)	Southeast(?)	-	-	Precambrian
EEE	Northwest(?)	Northeast(?)	100	80	Precambrian
FFF	Northeast(?)	West	80		Interbedded Salt through Pennsylvanian
GGG[b]	Northwest	Southwest	-	-	Interbedded Salt through Top of Salt
HHH[b]	Northwest	Northeast	-	-	Interbedded Salt through Top of Salt
III	Northwest(?)	Southwest(?)	-	-	Pennsylvanian
JJJ[b]	Northwest	Southwest	-	-	Precambrian through Mississippian
KKK[b]	Northwest	Northeast	-	-	Top of Salt

(a) 1 ft = 0.3048 m.

(b) Faults interpreted solely from well control data.

(c) Faults MM through UU, WW and YY are located north of this study area near Salt Valley, or south of the area near Elk Ridge, and are not discussed in this report.

Table 3-2. Faults Identified Solely on Well Data

Fault	Well Data
AAA	Mt. Fuel Milk Ranch: Sec. 32, T37S-R20E Pan Am #2 Elk Ridge: Sec. 18, T35S-R20E Union Oil of Calif.: Sec. 2, T35S-R20E E.B. LaRue #1 Butler Wash: Sec. 3, T38S-R21E
BBB	Pure La Sal: Sec. 19, T29S-R24E Gulf Chevron Fed: Sec. 24, T29S-R23E
GGG	Pure: Sec. 3, T29S-R24E Belco State: Sec. 33, T30S-R24E Gulf Chevron Fed: Sec. 24, T29S-R23E Pure La Sal: Sec. 19, T29S-R24E
HHH	Belco State: Sec. 32, T29 1/2-R24E Pure 2 NW Lisbon: Sec. 3, T30S-R24E Opine St. Small Fry: Sec. 2, T30S-R24E Pure St.: Sec. 2, T30S-R24E
JJJ	Pan Am Lockhart: Sec. 26, T28S-R20E Pam Charles: Sec. 31, T28S-R21E Damson: Sec. 5, T29S-R21E
KKK	Pan Am Charles: Sec. 31, T28S-R21E Kimbark Braun: Sec. 33, T28S-R21E Damson: Sec. 5, T29S-R21E Husky Fed: Sec. 15, T29S-R21E Pan Am Lockhart: Sec. 26, T28S-R20E

Table 3-3. Lockhart Basin/Hatch Mesa Seismic Lines and Faults

Line[a]	Location[b]	Fault[c]	Comments
1	East of LB	CCC, O, X	X: sinuous trace; not a graben; O: fault plane migrated.
2	Northeast of LB	V, W	
3	Southern edge of LB	O, U	Line also used to delimit salt at LB perimeter; fault planes migrated.
4	North of LB	V	Short line.
5	Southeast of line 2	X	
9	Eastern edge of LB	Q	Short line.
10	Southeast of LB	O, S	Extension of line 27; faults form a downdropped wedge.
11	Northwest of line 10	O, S, U	Fault planes migrated.
12	Southeast of line 10	O	
13	Northwest of line 5	X	
14	Northwest of Trough Springs Fault	none	Same route as northern portion of line 31.
15	Southeast of HM	O	
16	Southeast of line 15	B	B: Flat Iron Mesa.
18	Across northeast end of line 12	T	
19	Southeast of line 15	B	B: Flat Iron Mesa.
23	West of HM	O, U	
24	Southeast of LB	O, Q	
25	Southeast of LB	U, O, T	
26	Across HM	O, T, DDD	O: fault plane migrated.

Table 3-3. Lockhart Basin/Hatch Mesa Seismic Lines and Faults (Page 2 of 2)

Line[a]	Location[b]	Fault[c]	Comments
27	South of HM	U, O, S	Adjoins line 10.
28	South of HM	O, P, S	O: sinuous fault trace.
29	Southeast of Bridger Jack Mesa	none	
31	Across HM	CCC, O, U, CC	CC: Flat Iron Mesa.
32	Across HM	O, U, S, ZZ	
38	West perimeter of LB	AA, III, FFF, D	FFF: Gibson dome fold; D: Flat Iron Mesa
39	In LB	O	

(a) Locations of lines are shown on Figure 2-1, Sheets 2 and 3.
(b) LB = Lockhart Basin; HM = Hatch Mesa.
(c) Faults cutting top of salt or Mississippian are shown relative to seismic lines on Figures 3-1 and 3-2.

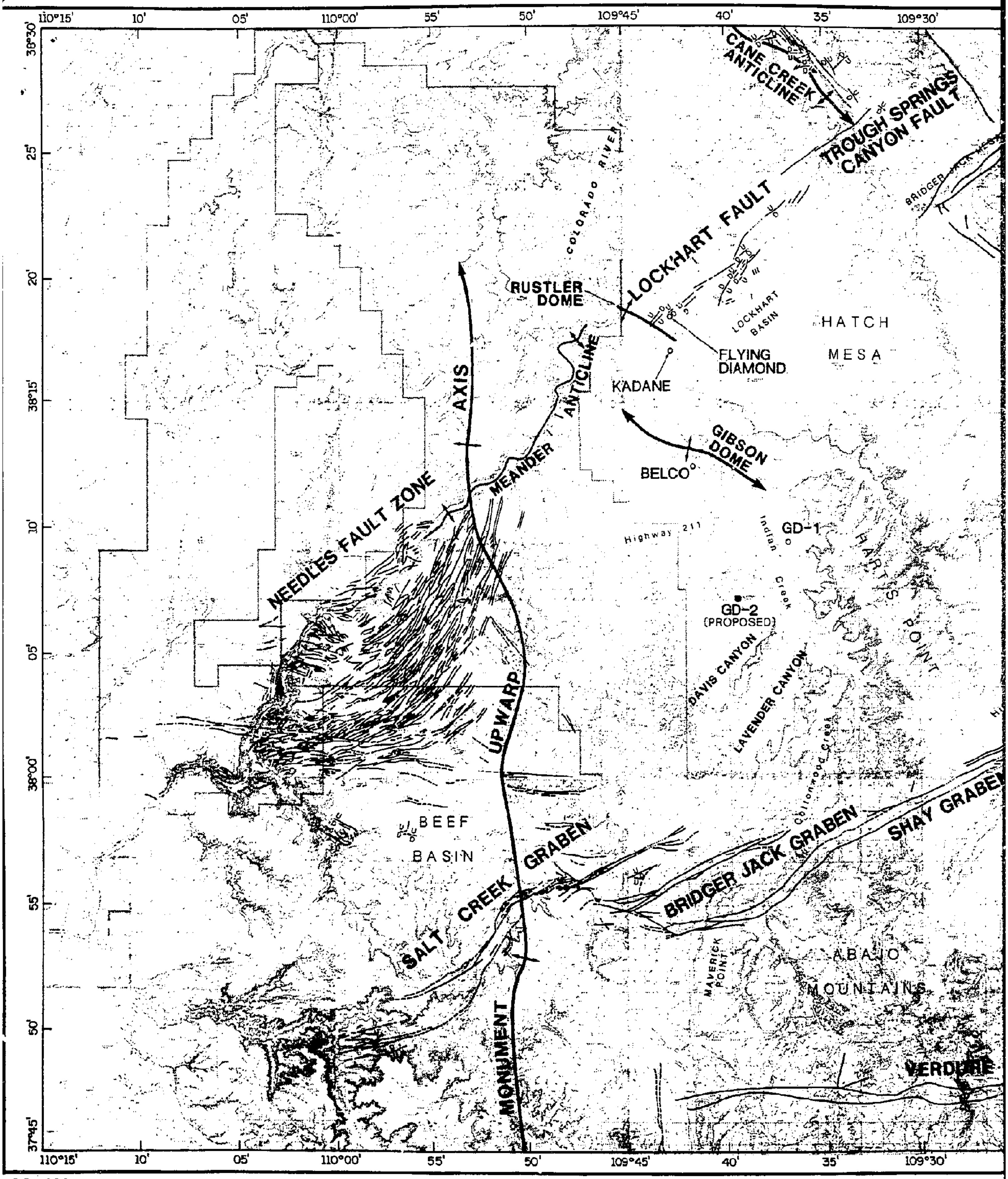
Table 3-4. Depth to Salt Cycle 6 - Davis Canyon

Location	Topographic Elevation at Point[a] (ft)	Elevation of Top of Salt (ft)	Depth to Top of Salt (ft)	Depth to Top of Salt Cycle 6[b] (ft)
A	5,020	2,238	2,782	2,972
B	5,040	2,283	2,757	2,947
C	5,080	2,323	2,757	2,947
D	5,100	2,413	2,687	2,877
E	5,130	2,433	2,697	2,877
F	5,150	2,478	2,672	2,862

Note: 1 ft = 0.3048 m.

(a) Estimated from 1:24,000-scale topographic map.

(b) Calculated as depth to top of salt plus 190 feet, the interval between the top of Salt Cycle 6 in borehole GD-1.



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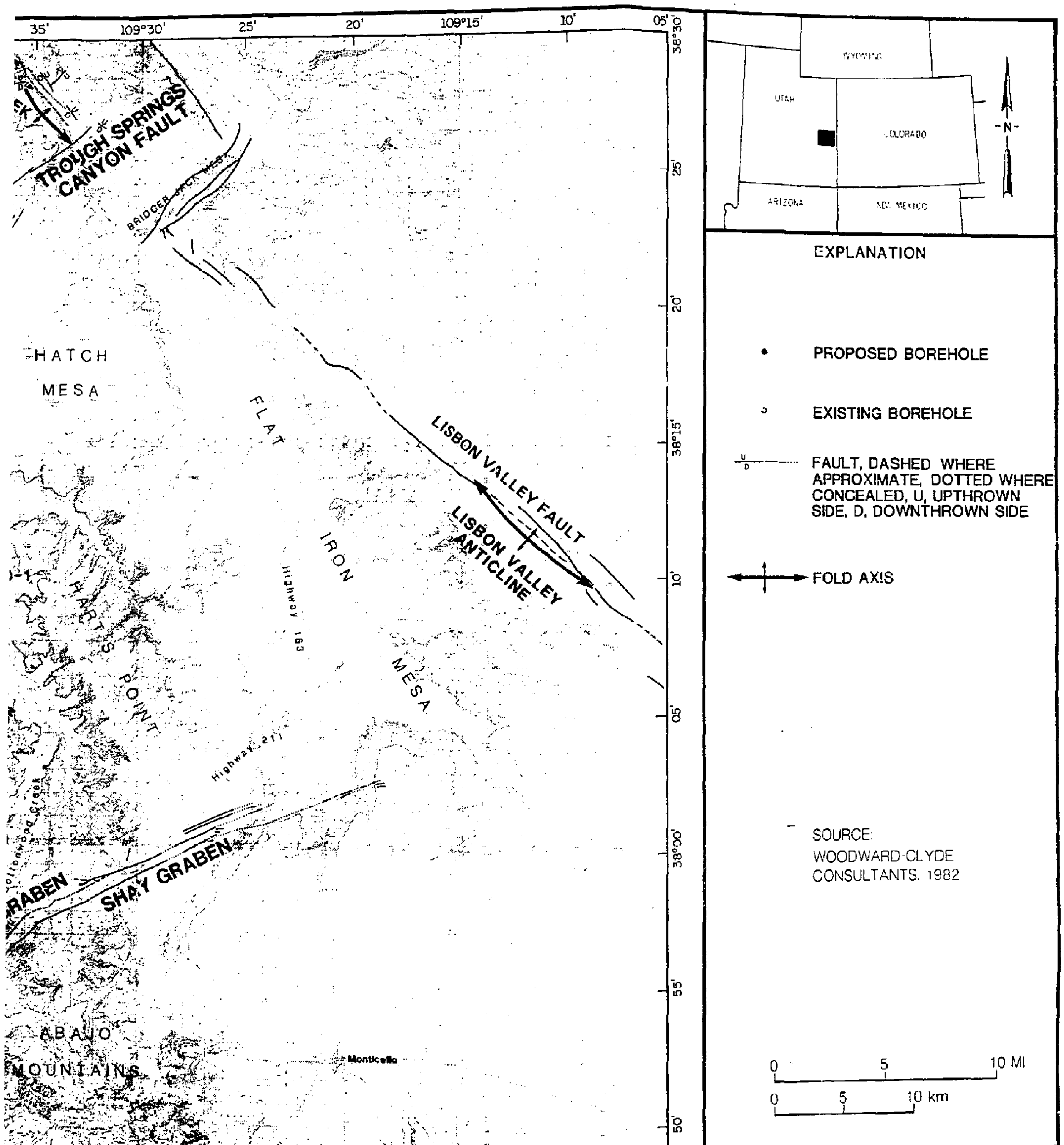
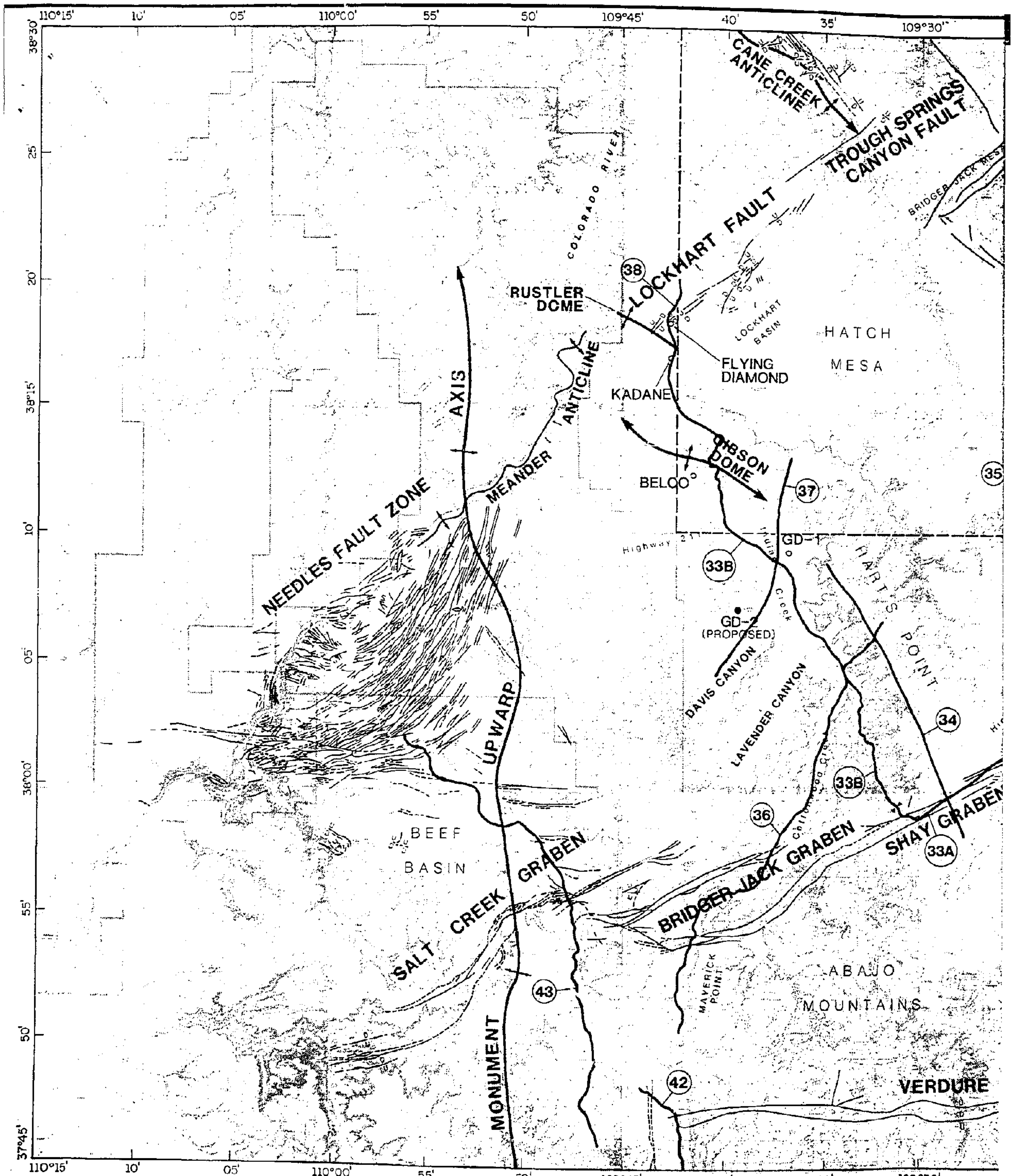


MAP OF GEOLOGIC STRUCTURES
DAVIS AND LAVENDER CANYONS
STUDY AREA

Project No. 17000
Woodward-Clyde Consultants

Figure 1–1



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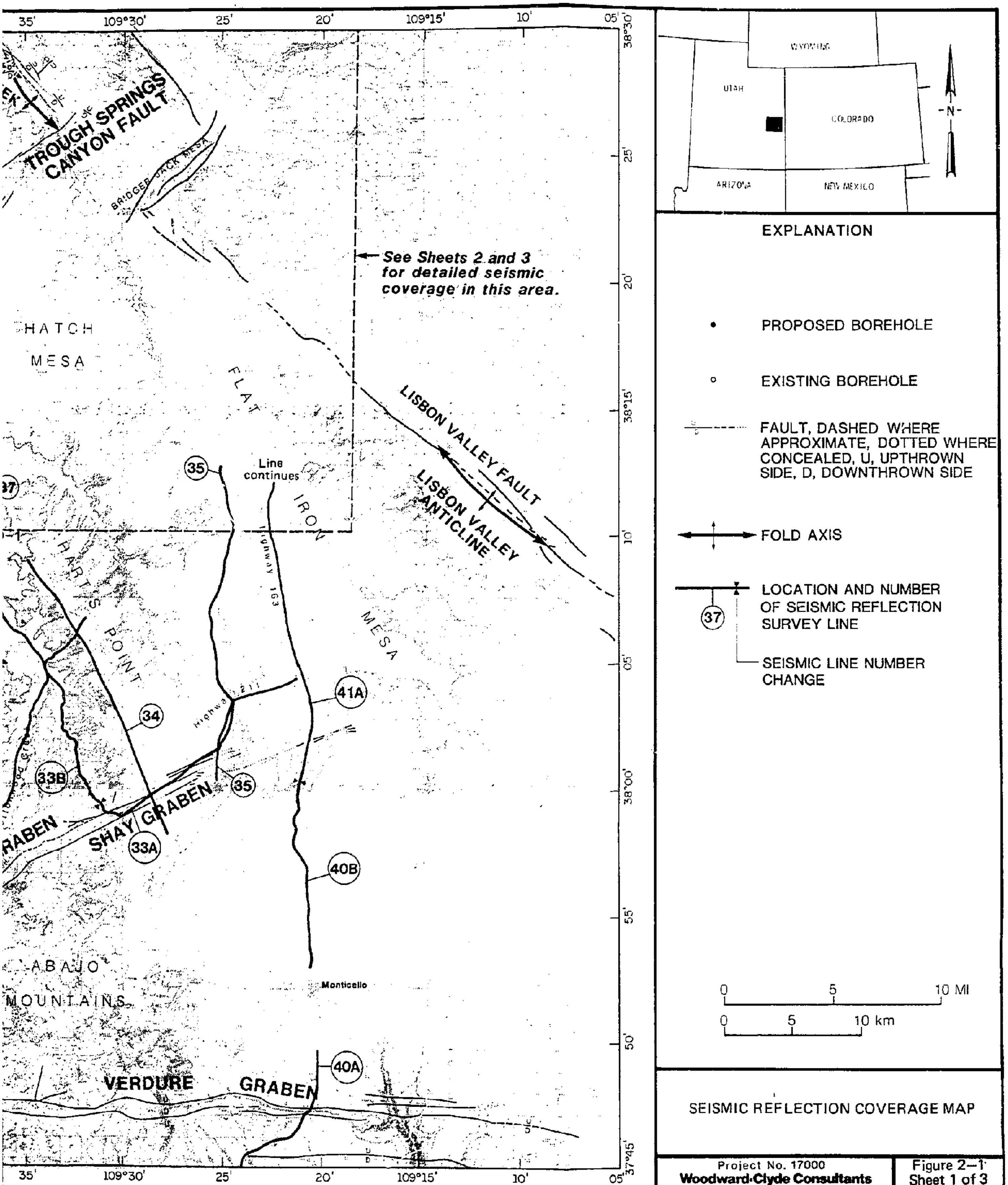
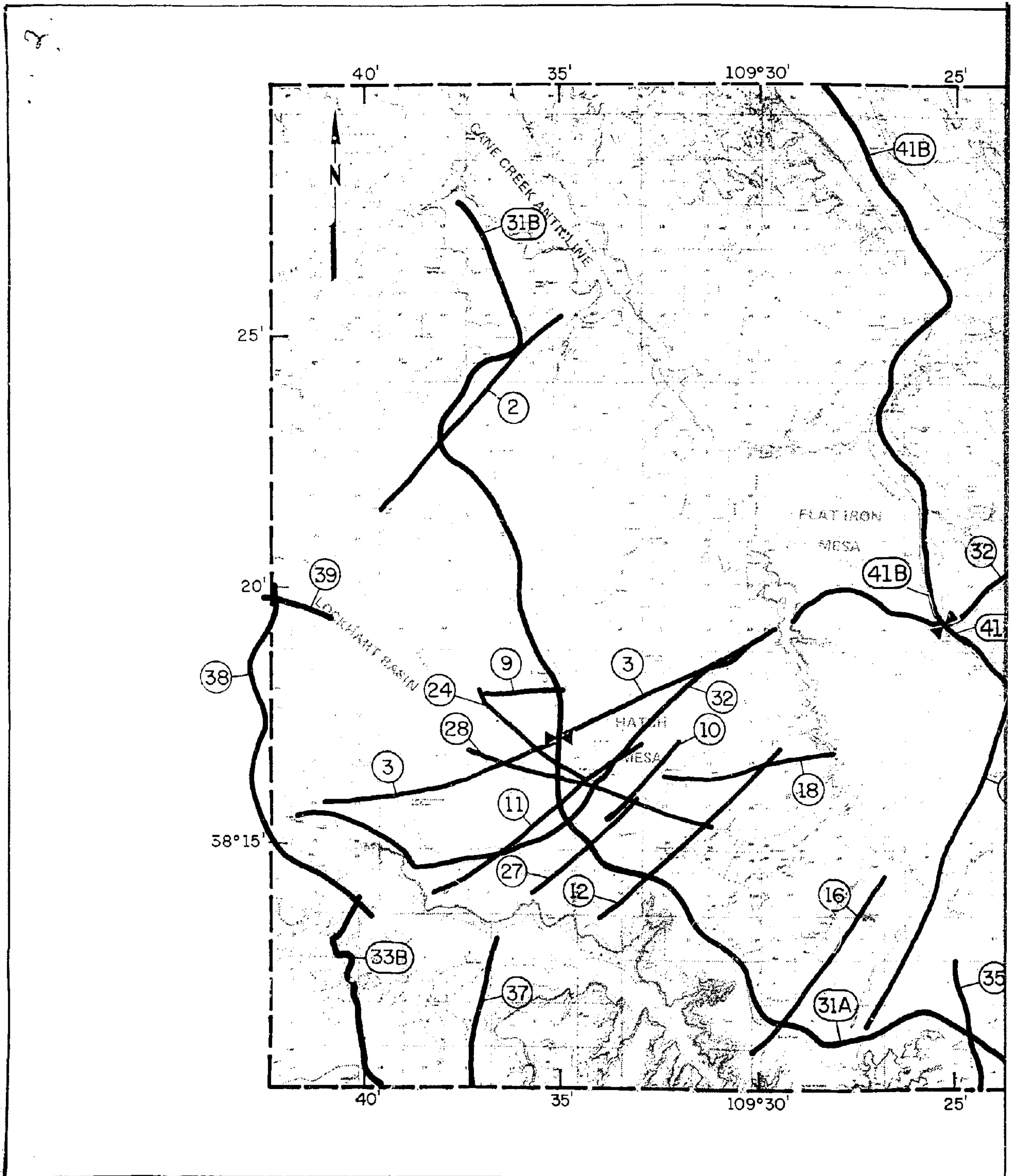

TROUGH SPRINGS CANYON FAULT
BRIDGER JACK MESA
See Sheets 2 and 3 for detailed seismic coverage in this area.
HATCH MESA
FLAT IRON MESA
LISBON VALLEY FAULT
LISBON VALLEY ANTICLINE
Line continues
Highway 163
Highway 211
HARTS POINT
SHAY GRABEN
GRABEN
ABAJO MOUNTAINS
Monticello
VERDURE GRABEN
35
34
33B
33A
37
41A
40B
40A
109°30'
25'
20'
109°15'
10'
05'
38°30'
38°15'
38°00'
37°45'
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
N
EXPLANATION
PROPOSED BOREHOLE
EXISTING BOREHOLE
FAULT, DASHED WHERE APPROXIMATE, DOTTED WHERE CONCEALED, U, UPTHROWN SIDE, D, DOWNTHROWN SIDE
FOLD AXIS
LOCATION AND NUMBER OF SEISMIC REFLECTION SURVEY LINE
SEISMIC LINE NUMBER CHANGE
0 5 10 MI
0 5 10 km
SEISMIC REFLECTION COVERAGE MAP
Project No. 17000
Woodward-Clyde Consultants
Figure 2—1
Sheet 1 of 3



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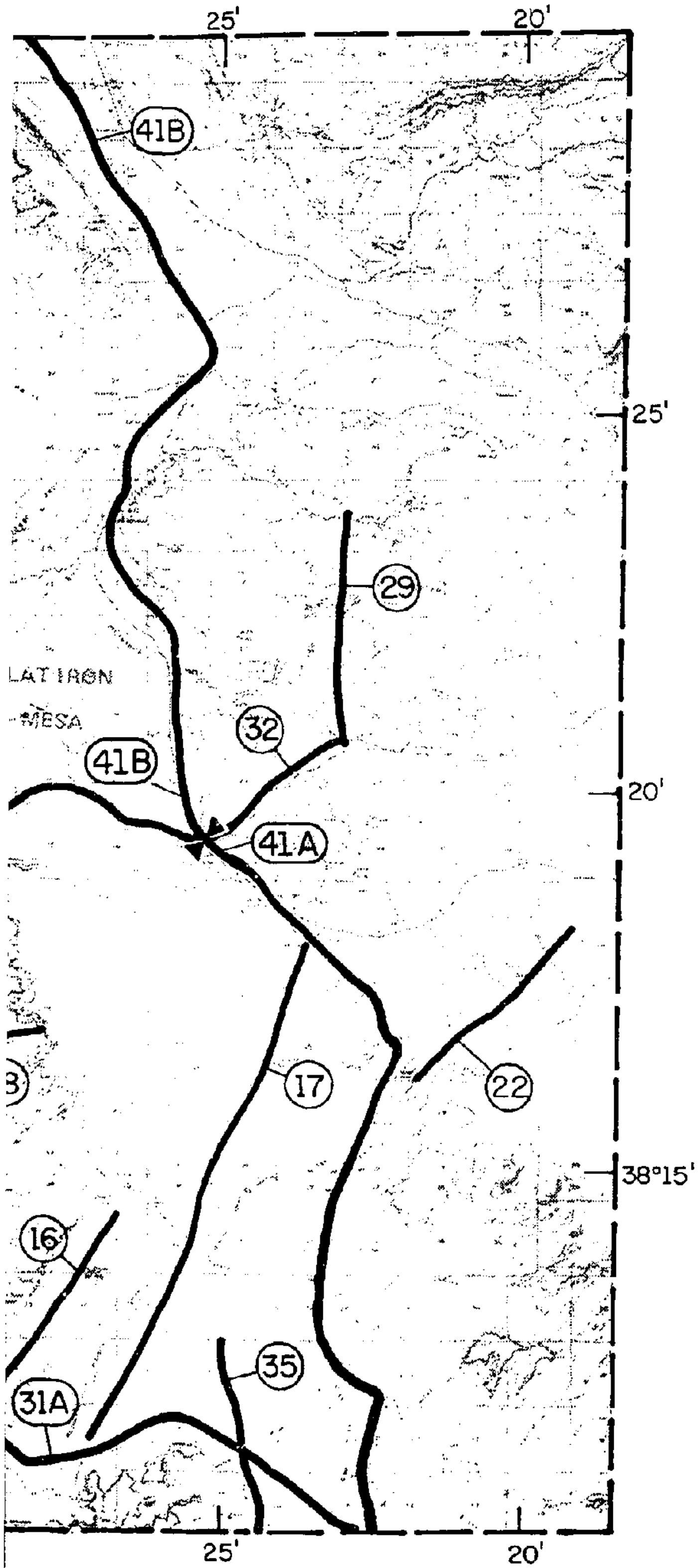


EXPLANATION

LOCATION AND NUMBER OF SEISMIC REFLECTION SURVEY LINE

SEISMIC LINE NUMBER CHANGE

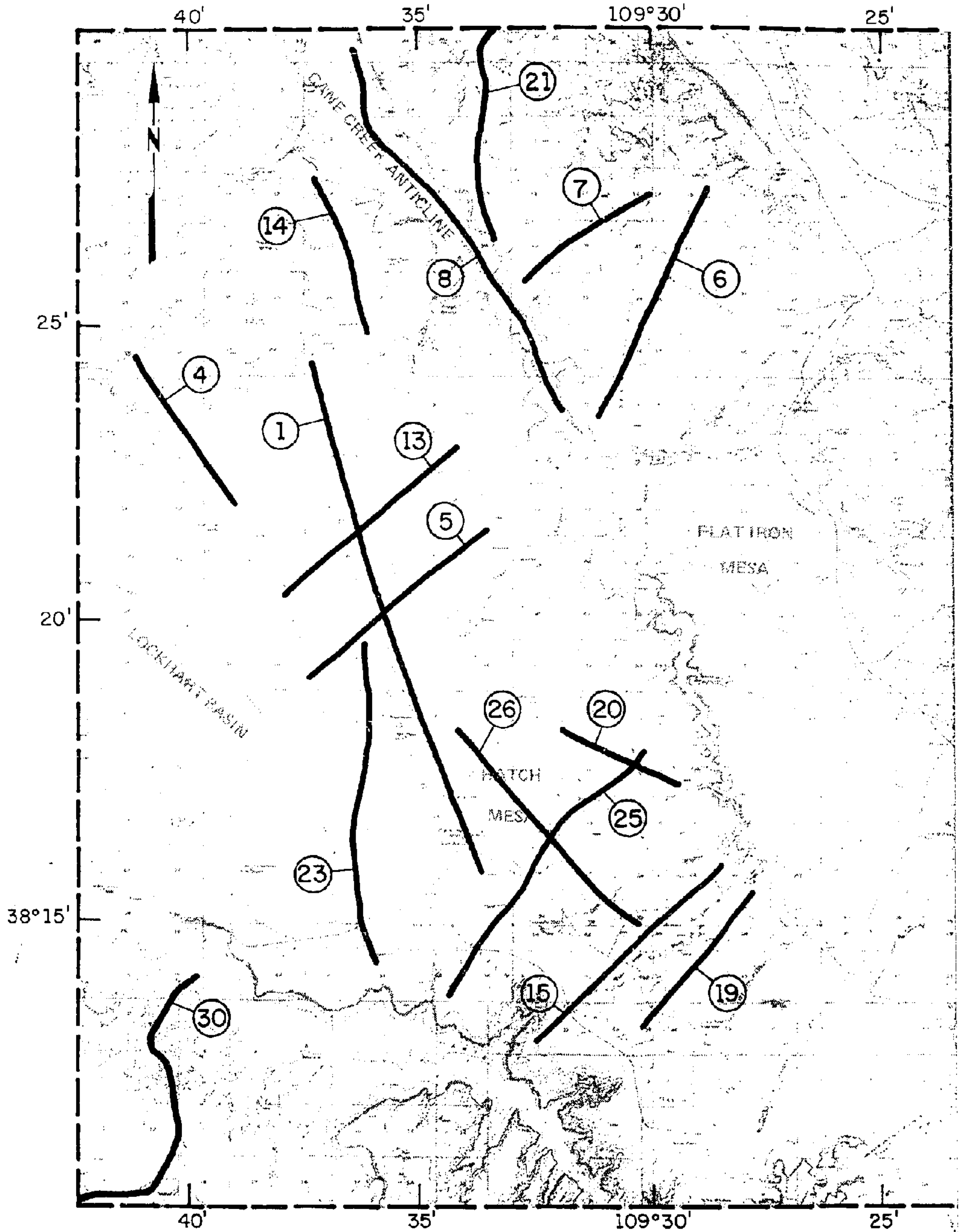
See Sheet 3 for additional coverage

0 2 4 6 Mi

0 2 4 6 km

SEISMIC REFLECTION COVER 1AP

Project No. 17000 **Woodward-Clyde Consultants**	ıgure 2–1 Sheet 2 of 3



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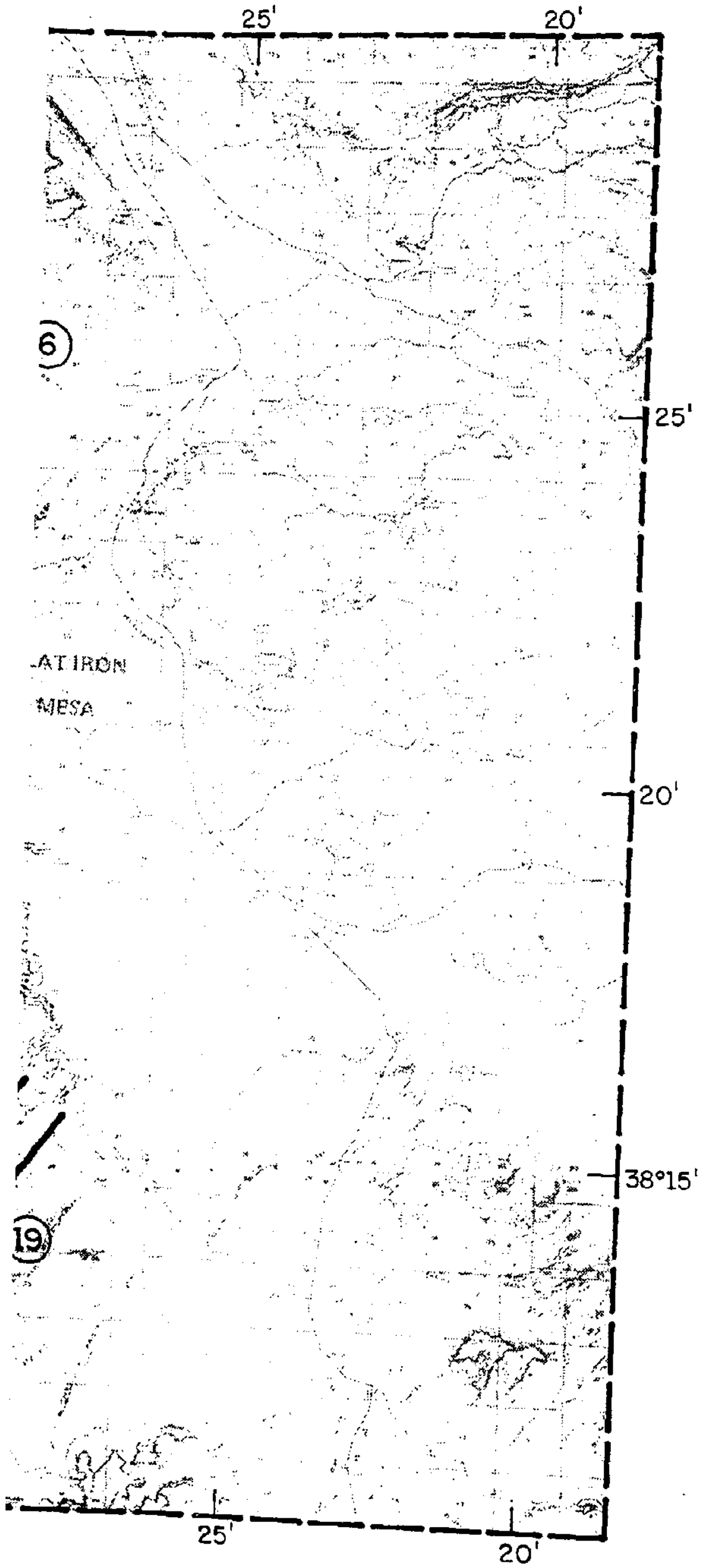


EXPLANATION

7 LOCATION AND NUMBER OF SEISMIC REFLECTION SURVEY LINE

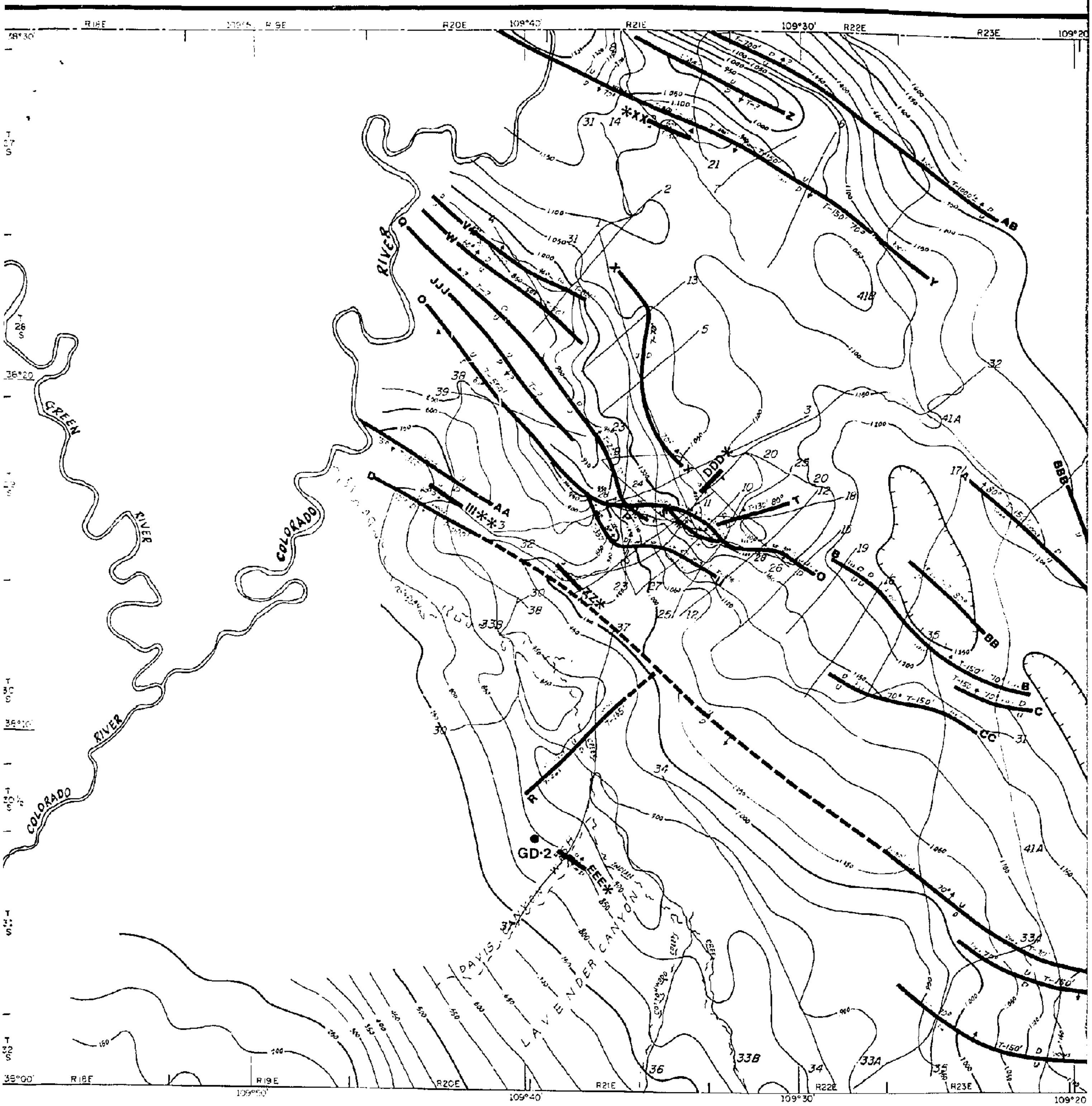
See Sheet 2 for additional coverage

0 2 4 6 Mi

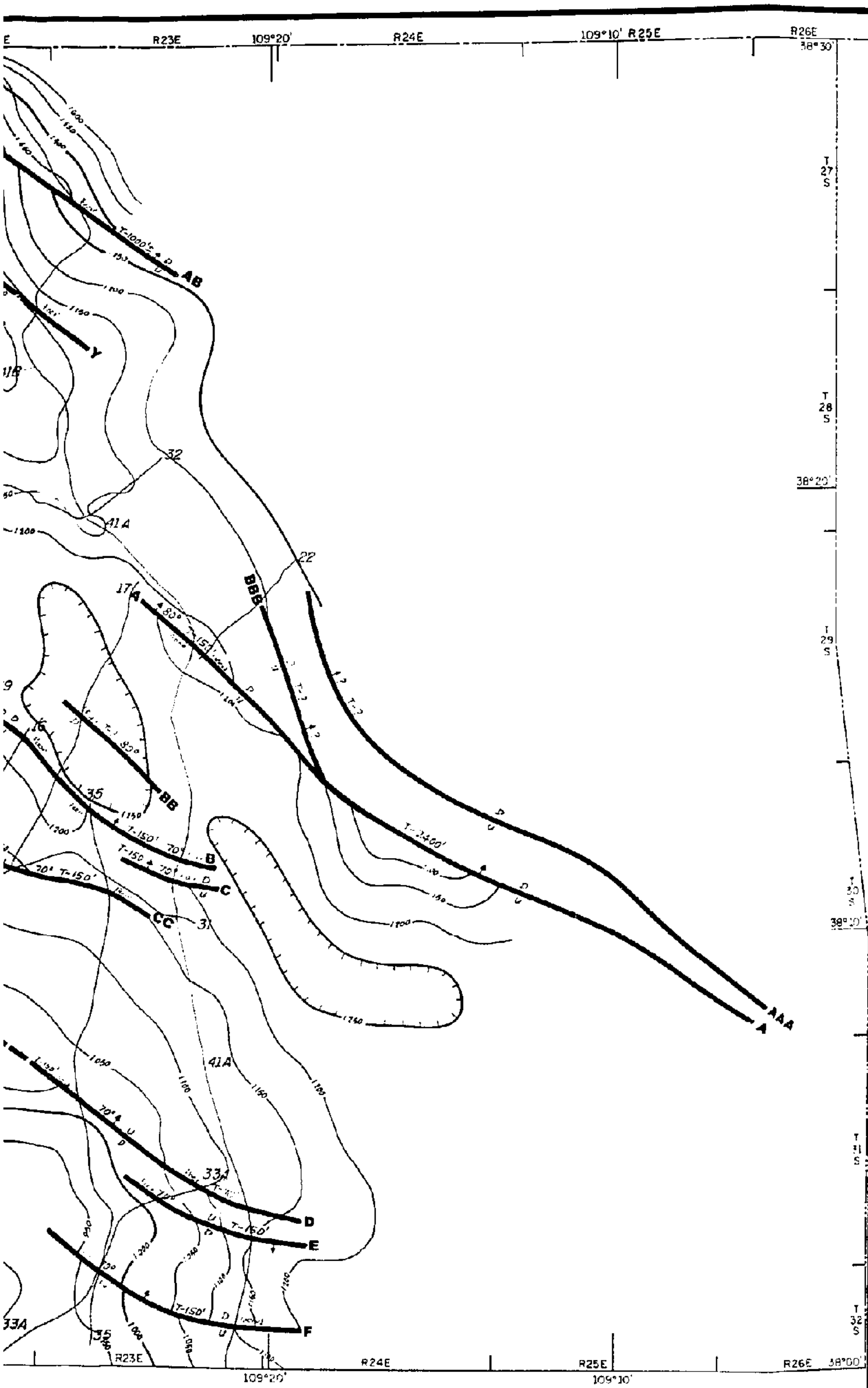
0 2 4 6 km

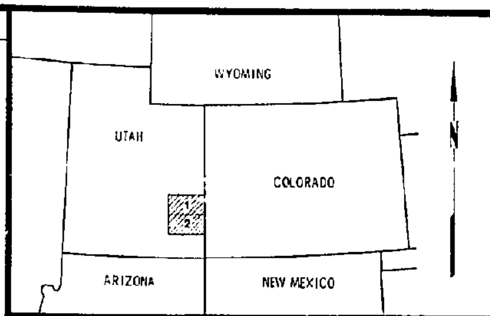
SEISMIC REFLECTION COVERAGE MAP

Project No. 17000 **Woodward-Clyde Consultants**	Figure 2–1 Sheet 3 of 3



ⅮG 1539
EV.0-8/2/83





EXPLANATION

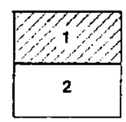
—1200— REFLECTION TIME CONTOUR, .050 SECONDS ≈ 325 FEET

FAULT; E = FAULT DESIGNATION, U = UPTHROWN SIDE, D = DOWNTHROWN SIDE, T-70' = THROW IN FEET, 70° = DIP

33 ...... SEISMIC REFLECTION LINE WITH LINE NUMBER

* DISPLACES ONLY PRECAMBRIAN

** DISPLACES ONLY PENNSYLVANIAN



NOTE: QUALITY RATINGS (GOOD, FAIR AND POOR) REFER TO THE INTERPRETABILITY OF THE FAULTS. SOME QUALITY RATINGS HAVE BEEN OMITTED IN THE HATCH MESA AREA BECAUSE OF THE DENSE COVERAGE.

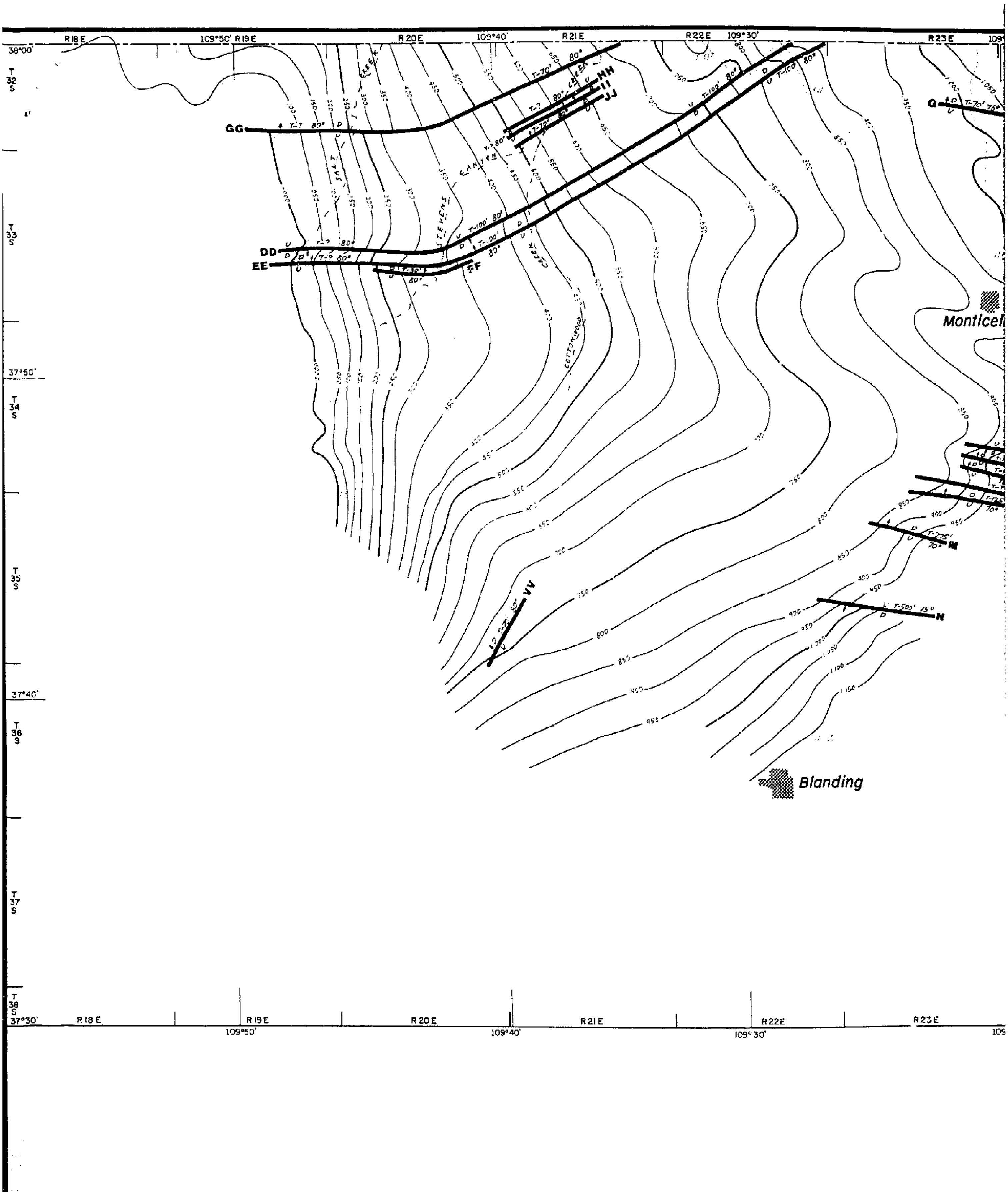
0 2 4 6 8 Mi

0 2 4 6 8 km

REFLECTION TIME CONTOURS, TOP OF MISSISSIPPIAN, MISSISSIPPIAN FAULTS AND SEISMIC LINES

Project No. 17000
Woodward-Clyde Consultants

Figure 3-1
Sheet 1 of 2



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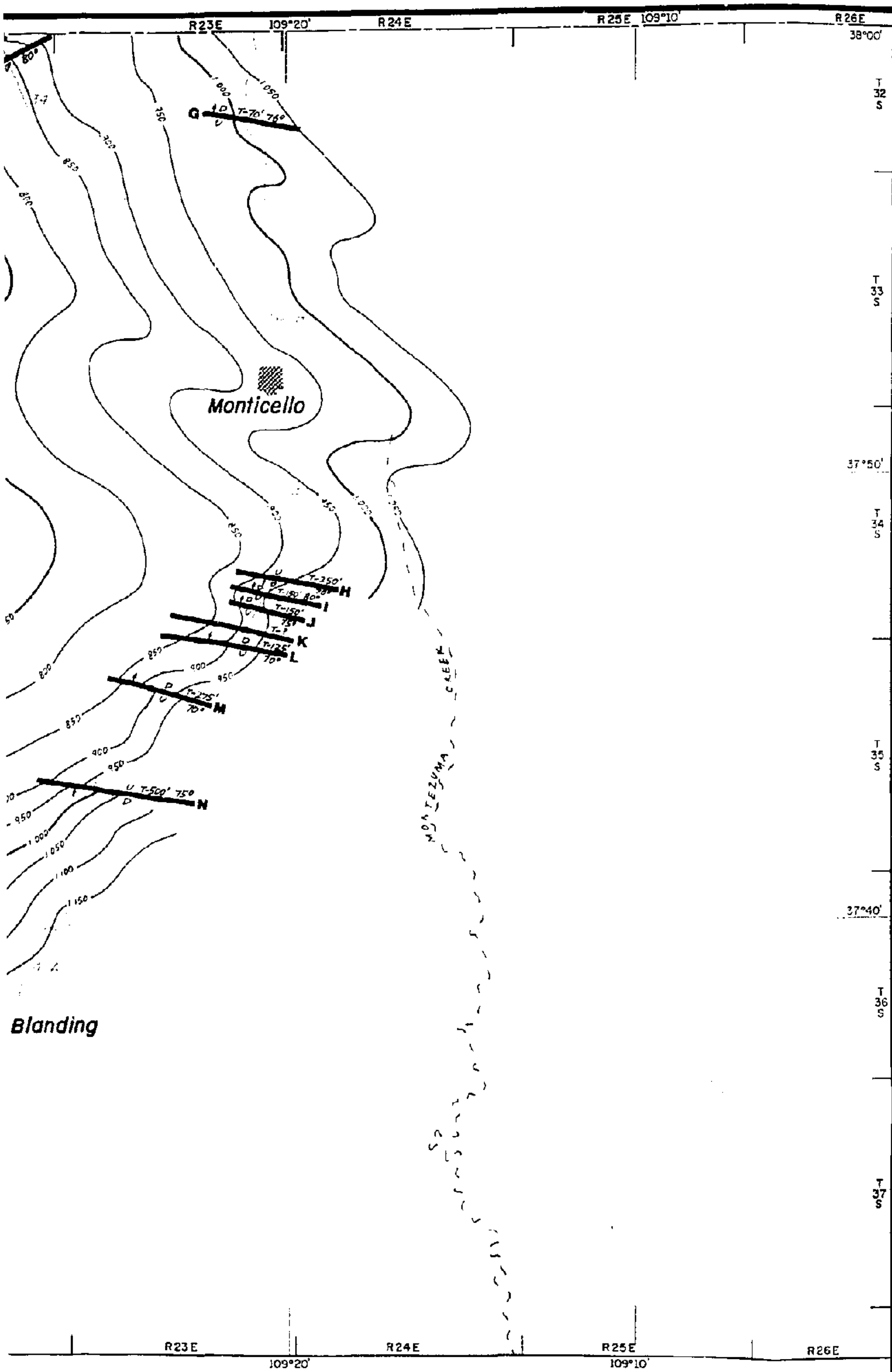


EXPLANATION

REFLECTION TIME CONTOUR, .050 SECONDS ≈ 325 FEET

FAULT; E = FAULT DESIGNATION, U=UPTHROWN SIDE, D=DOWNTHROWN SIDE, T–70' = THROW IN FEET, 70° = DIP

SEISMIC REFLECTION LINE WITH LINE NUMBER

1

2

NOTE: QUALITY RATINGS (GOOD, FAIR AND POOR) REFER TO THE INTERPRETABILITY OF THE FAULTS.

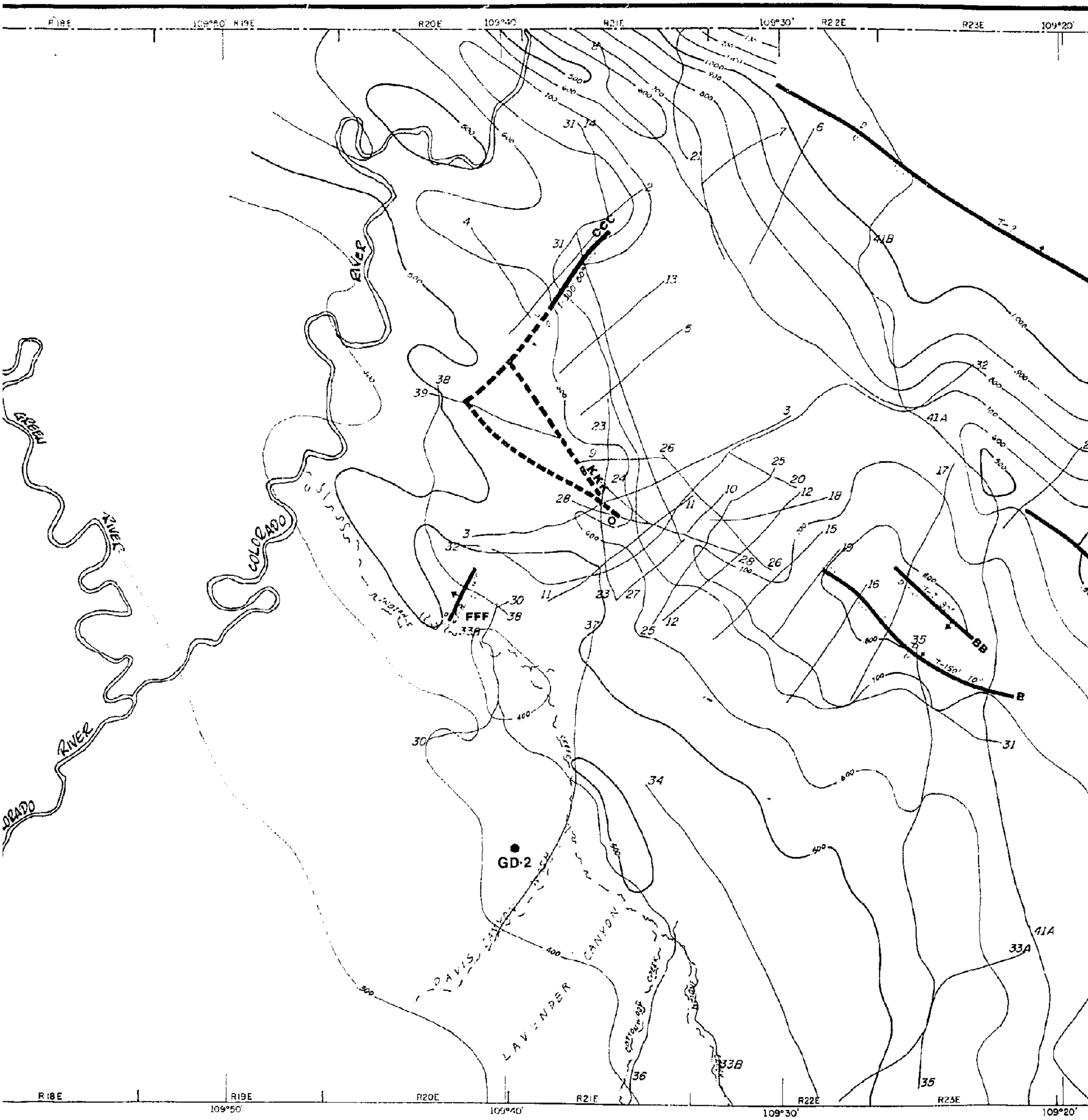
0 2 4 6 8 Mi

0 2 4 6 8 km

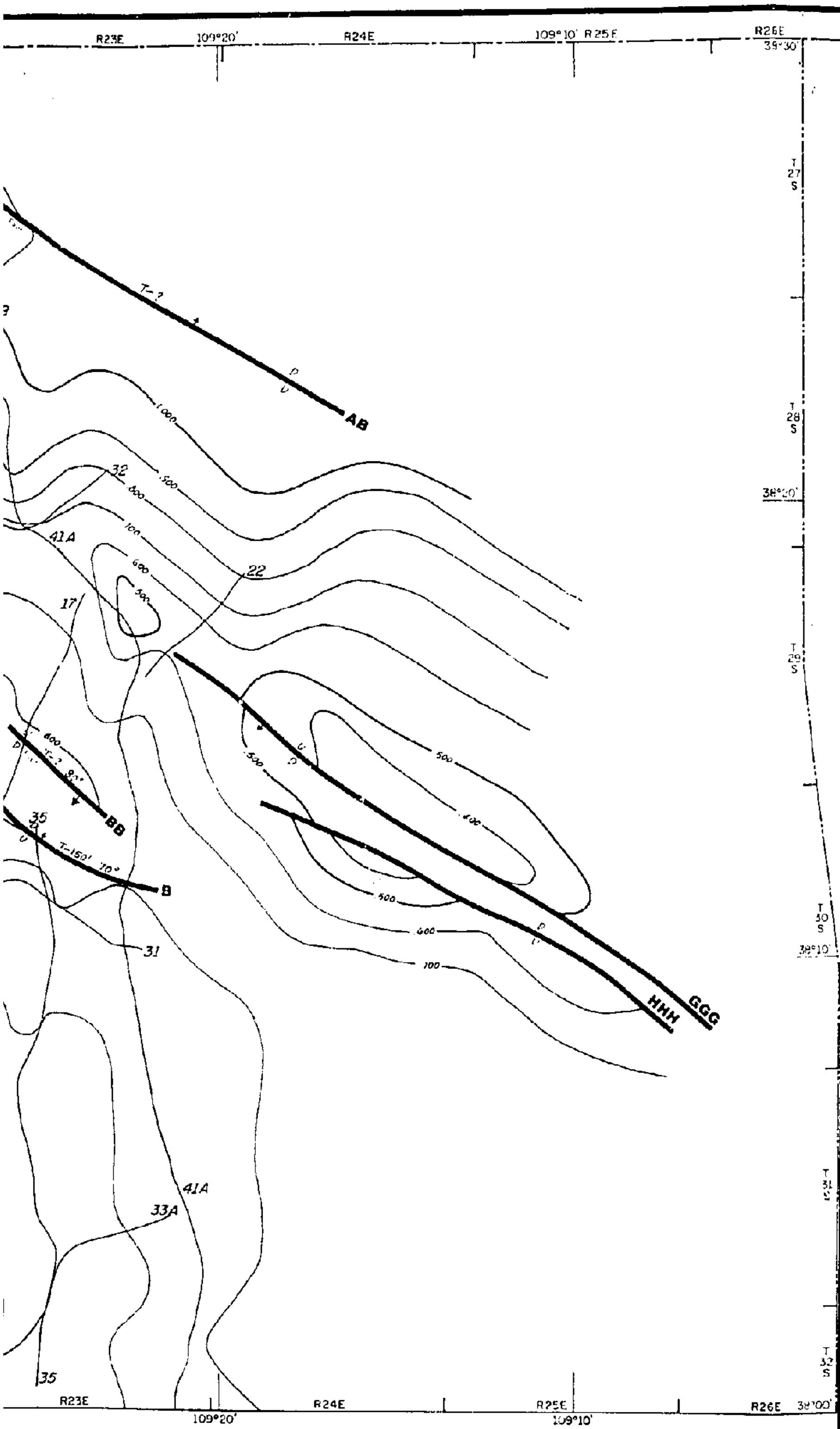
REFLECTION TIME CONTOURS, TOP OF MISSISSIPPIAN, MISSISSIPPIAN FAULTS AND SEISMIC LINES

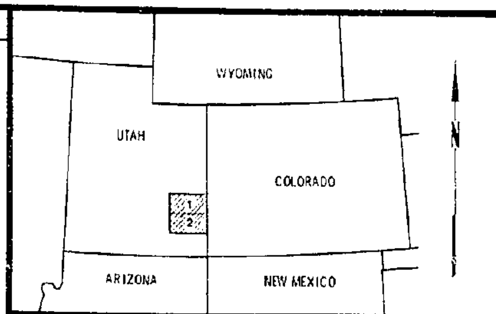
Project No. 17000
Woodward-Clyde Consultants

Figure 3–1
Sheet 2 of 2


R18E
109°50'
R19E
R20E
109°40'
R21E
109°30'
R22E
R23E
109°20'
GREEN
RIVER
COLORADO
RIVER
GD-2
CCC
FFF
BB
B
DAVIS
CANYON
LAVENDER
CANYON
41A
41B
33A
33B
35
36
34
31

1542
)-8/2/83





EXPLANATION

1,200 — REFLECTION TIME CONTOUR, .100 SECONDS ≈ 650 FEET

E — FAULT; E = FAULT DESIGNATION, U = UPTHROWN SIDE, D = DOWNTHROWN SIDE, T-70' = THROW IN FEET, 70° = DIP

33 — SEISMIC REFLECTION LINE WITH LINE NUMBER

NOTE: QUALITY RATINGS (GOOD, FAIR AND POOR) REFER TO THE INTERPRETABILITY OF THE FAULTS.

0 2 4 6 8 Mi

0 2 4 6 8 km

REFLECTION TIME CONTOURS, TOP OF SALT, TOP OF SALT FAULTS AND SEISMIC LINES

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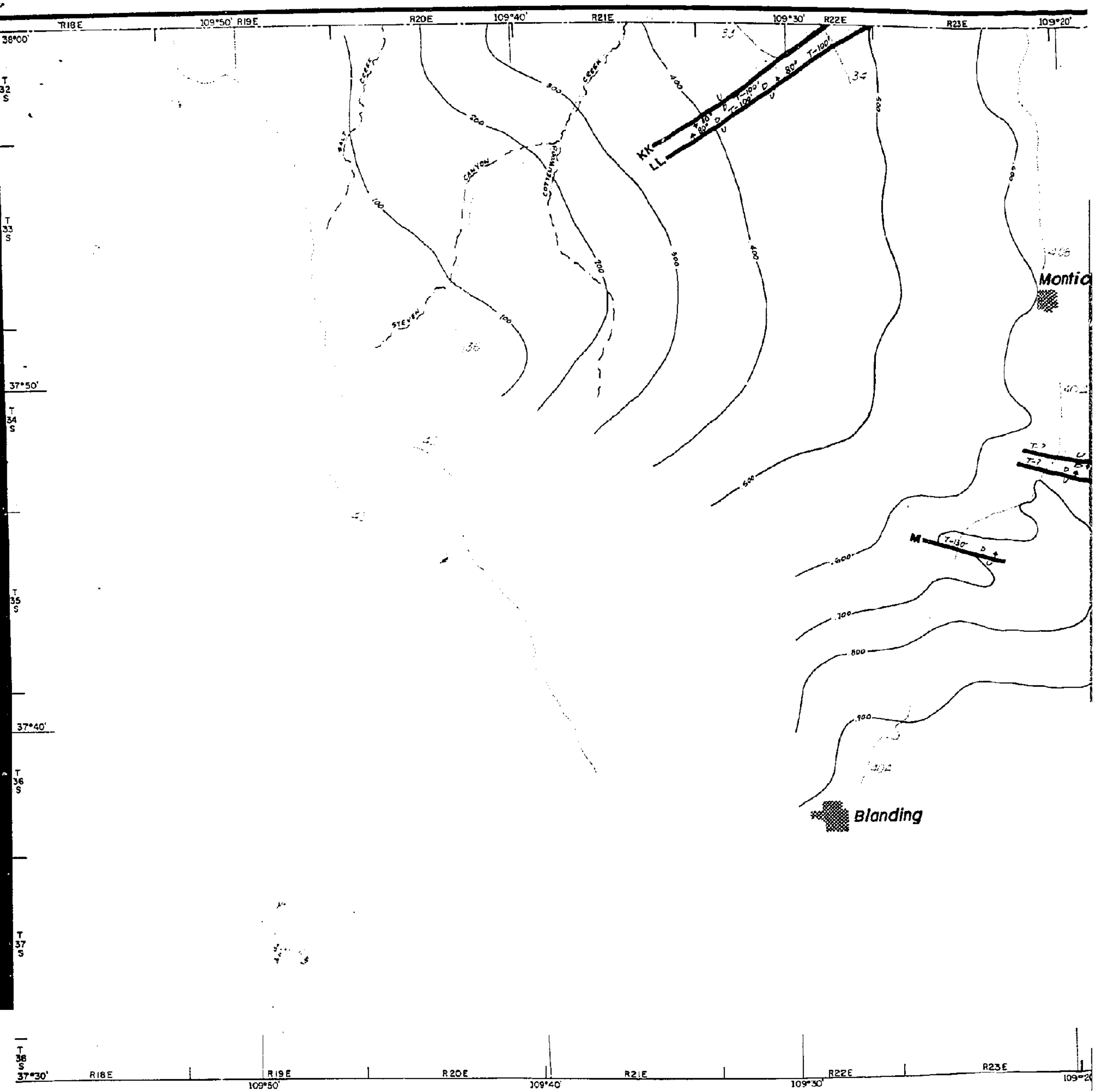
Figure 3–2
Sheet 1 of 2



OG 1543
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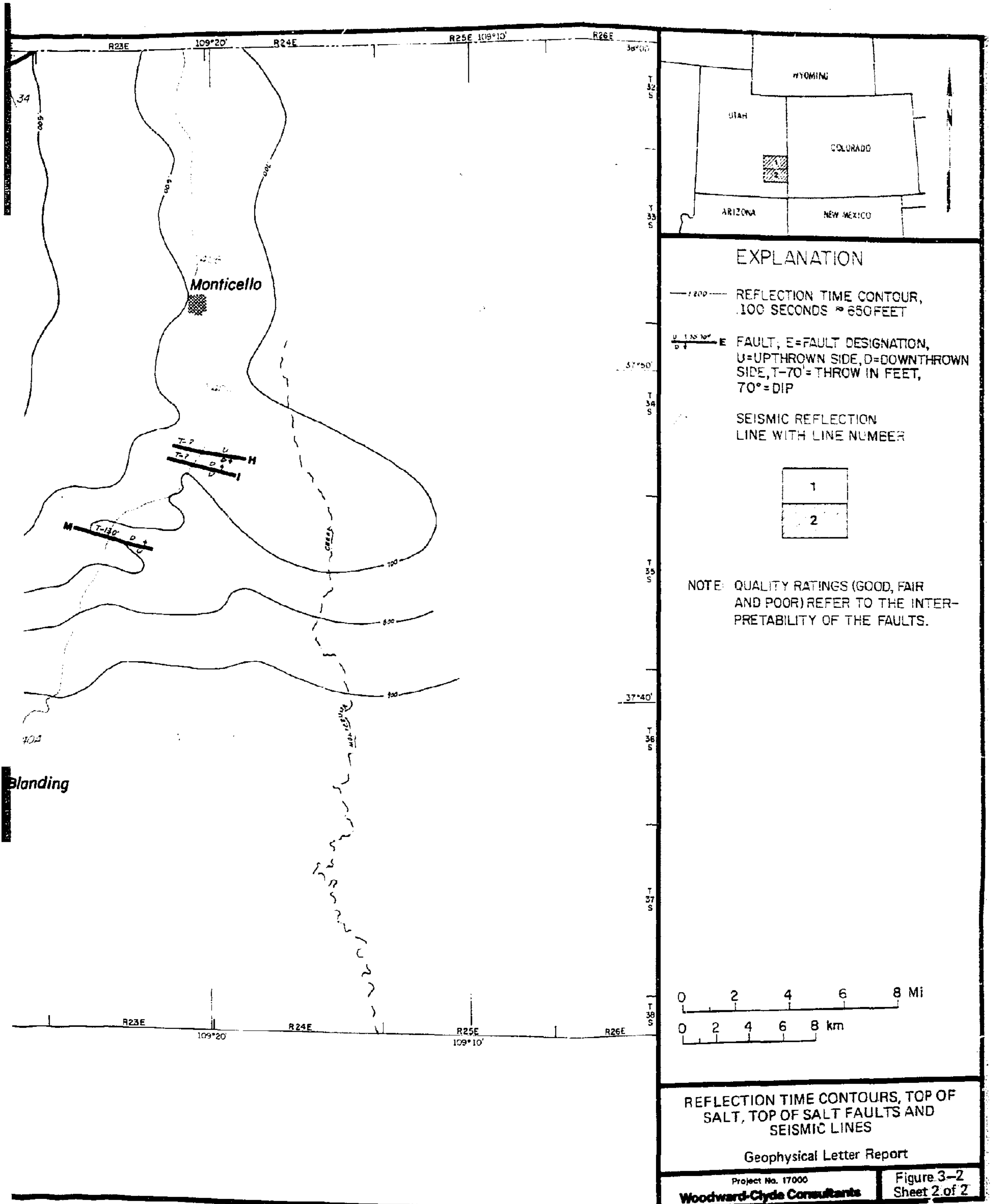

REFLECTION TIME CONTOURS, TOP OF SALT, TOP OF SALT FAULTS AND SEISMIC LINES

Geophysical Letter Report

Project No. 17000

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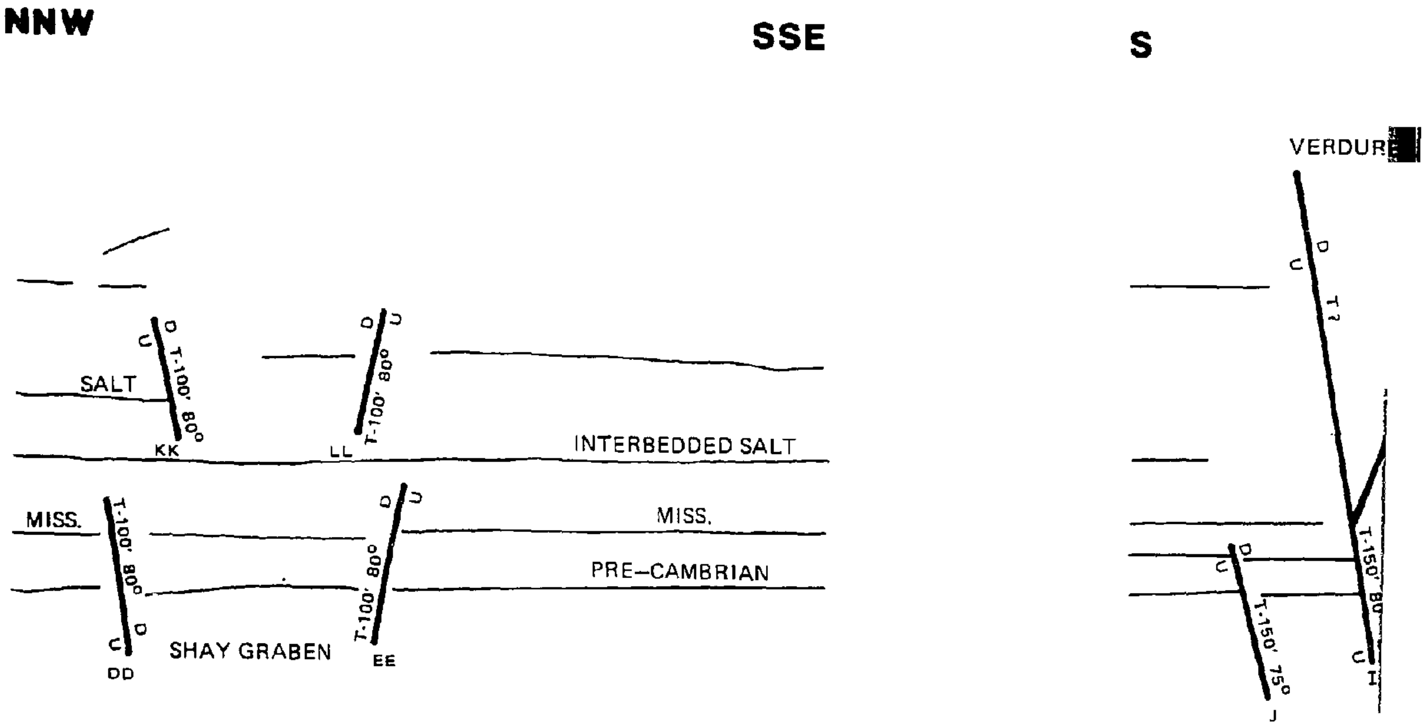
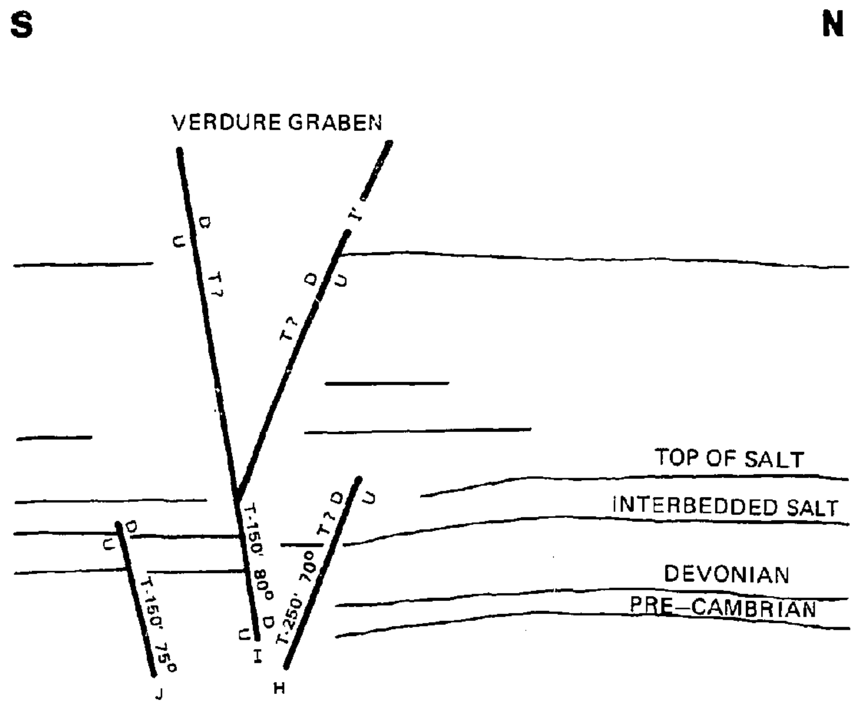
Figure 3-2
Sheet 2 of 2


NNW
SSE
S
VERDURE
SALT
T-100' 80°
KK
LL
INTERBEDDED SALT
MISS.
MISS.
PRE-CAMBRIAN
SHAY GRABEN
DD
EE
T?
T-150' 80
T-150' 75°
J
H



EXPLANATION

SALT — REFLECTOR WITH STRATIGRAPHIC IDENTIFICATION

U T-70' 70° D — FAULT. U=UPTHROWN SIDE, D=DOWNTHROWN SIDE, T–70'=THROW IN FEET, 70°=DIP

0 — 1 Mi

0 — 1 km

SCHEMATIC OF
NESTED FAULT CONFIGURATION

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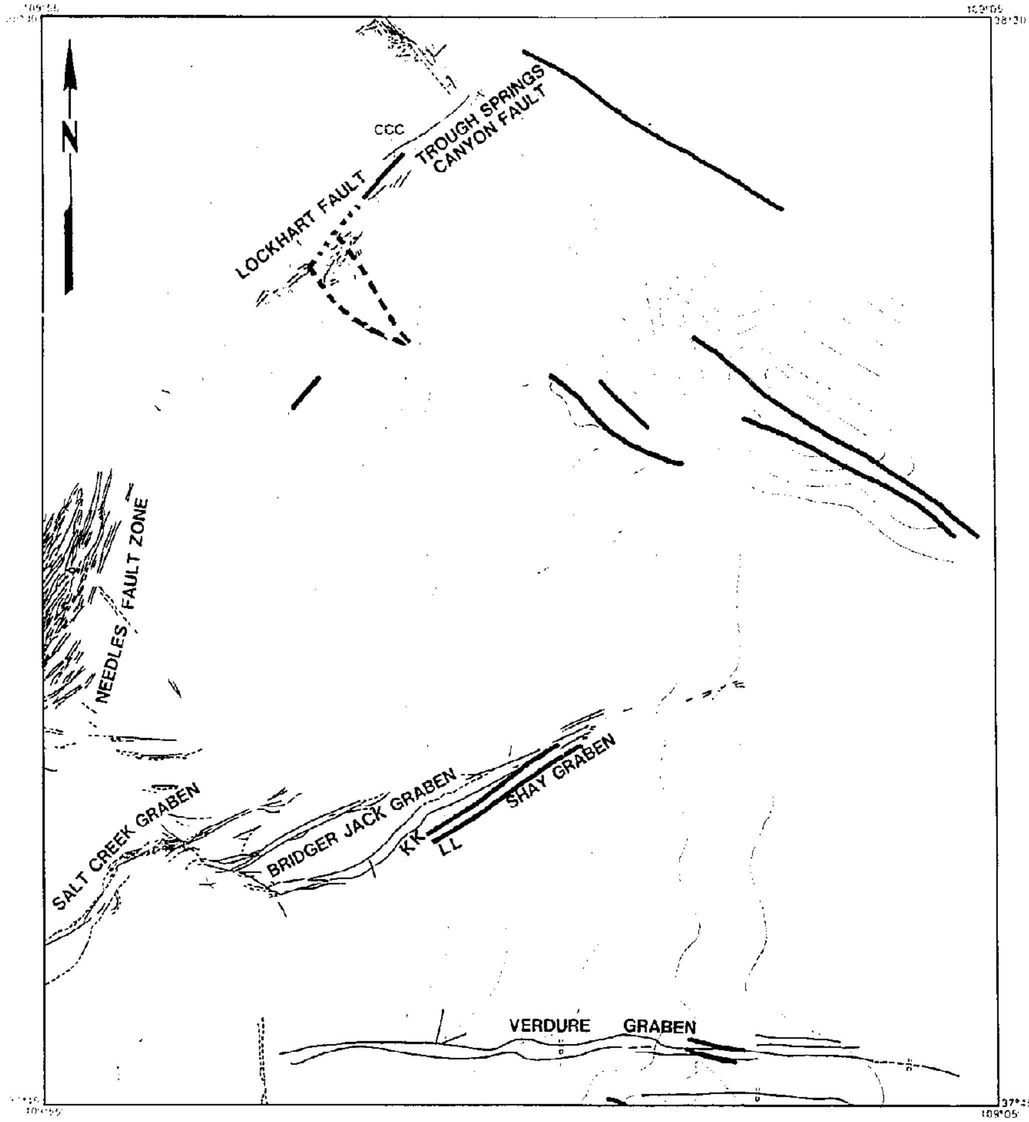
Figure 3–3



EXPLANATION

——— REFLECTION TIME CONTOUR, (See Figure 3–2)

– – – ——— SURFACE FAULT, DASHED WHERE UNCERTAIN OR CONCEALED

——— FAULT

0 5 10 15 MI

0 5 10 15 20 km

SURFACE FAULTS AND
FAULTS ON TOP OF SALT

LOG 1553
REV.1–10/9/84

Project No. 17000
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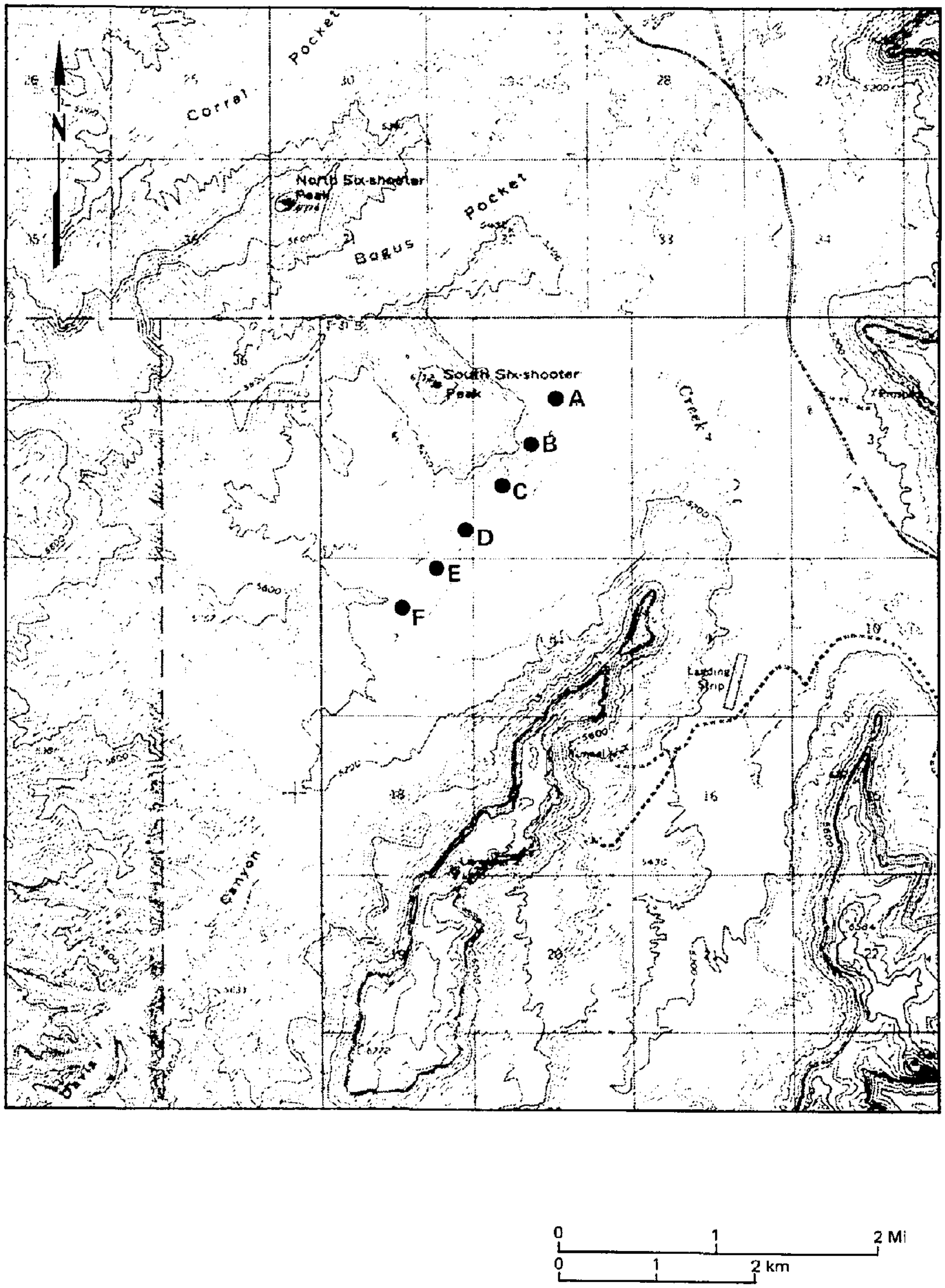
Figure 3–6



LOCATIONS OF SHOTPOINTS A–F
DAVIS CANYON
SEISMIC LINE 37

LOG 2088
REV.0–10/12/84

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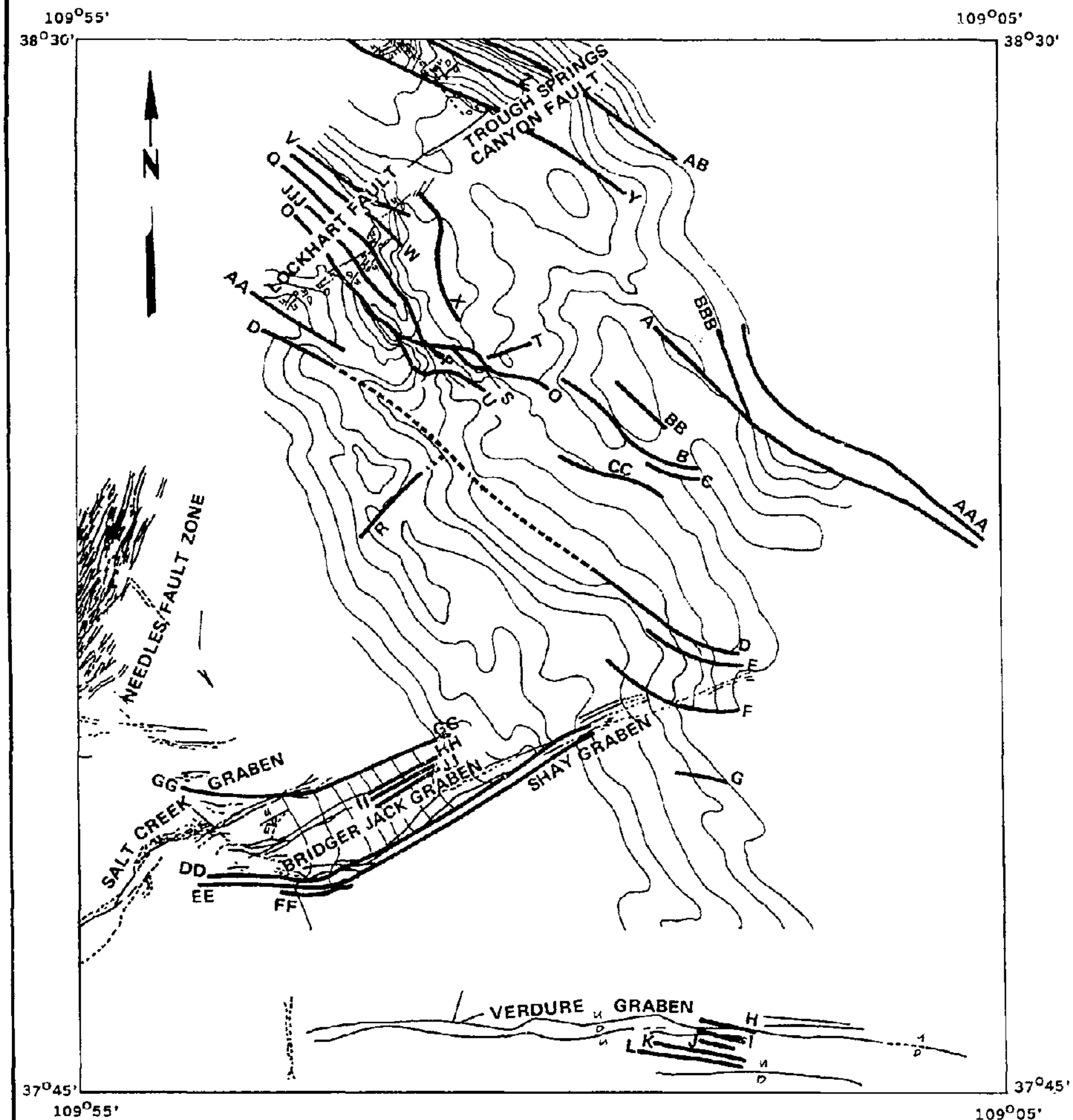
Figure 3–4



EXPLANATION

REFLECTION TIME CONTOUR, (See Figure 3–1)

SURFACE FAULT, DASHED WHERE UNCERTAIN OR CONCEALED

FAULT

0 5 10 15 Mi

0 5 10 15 20 km

SURFACE FAULTS AND FAULTS ON TOP OF MISSISSIPPIAN

LOG 1552
REV.1–10/9/84

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Figure 3–5

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